CORPS OF ENGINEERS, U. S. ARMY

# FLOOD-CONTROL OUTLET STRUCTURES FOR TUTTLE CREEK DAM, BIG BLUE RIVER, KANSAS

## HYDRAULIC MODEL INVESTIGATION

TECHNICAL MEMORANDUM NO. 2-396

CONDUCTED FOR

KANSAS CITY DISTRICT, CORPS OF ENGINEERS

BY

WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

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# PREFACE

Hydraulic model investigations of the flood-control outlet structures for Tuttle Creek Dam, Big Blue River, Kansas, were authorized by the Chief of Engineers in the first indorsement, dated 23 January 1952, to a letter dated 18 January 1952 from the Division Engineer, Missouri River Division, to the Office, Chief of Engineers. The investigations were accomplished during the period June 1952-January 1953 in the Hydraulics Division of the Waterways Experiment Station, by Messrs. J. H. Ables, Jr., N. V. Cowan, and H. H. Allen, under the general supervision of Messrs. T. E. Murphy and F. R. Brown.

Mr. Karl Jetter of the Missouri River Division, and Messrs. R. L. Gillis, L. E. Nelson, and E. Gaylord of the Kansas City District visited the Waterways Experiment Station during the course of the studies to discuss test results and to correlate these results with design work being accomplished concurrently.

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## SUMMARY

The hydraulic characteristics of the flood-control outlet structures for Tuttle Creek Dam were studied in a 1:25-scale model. The outlet structures comprised an intake, twin conduits, and twin stilling basins. Special attention was given to the control gates in the intake, which are to have upstream seals, and to the stilling basin. Tests also were directed toward determining hydraulic benefits of a transition from the horseshoe shape to a rectangular shape at the downstream end of the conduits.

Model tests demonstrated the adequacy of the design of the intake structure and intake transition, and indicated that the gate with upstream seals would operate satisfactorily. While the use of a transition to a rectangular shape at the conduit outlet improved flow conditions, the degree of improvement was not considered sufficient to justify the increased cost of construction.

Some modifications to the stilling-basin design were indicated. Raising the basin floor 5 ft and shortening the wall dividing the twin basins by 50 ft effected economies in construction and at the same time provided basin performance equivalent to that of the original design. Also, it was determined that the parallel walls extending into the exit channel could be replaced with curved wing walls, thereby materially reducing erosion tendencies in the exit area. Tests further demonstrated the effectiveness of the two rows of baffle piers and stepped end sill of the original design in stabilizing hydraulic jump action in the basin.

# FLOOD-CONTROL OUTLET STRUCTURES FOR TUTTLE CREEK DAM
# BIG BLUE RIVER, KANSAS

## Hydraulic Model Investigation

## PART I: INTRODUCTION

### Pertinent Features of Tuttle Creek Dam*

1. The Tuttle Creek Dam, proposed for construction on the Big Blue River about six miles north of Manhattan, Kansas (fig. 1), will provide flood-control benefits and assist in development of water resources in the Kansas River valley. It is one of a number of units in a general flood-control plan for the entire Missouri River Basin. The Tuttle Creek project consists of a rolled-fill earth dam, a gated spillway, and flood-control outlet structures. The dam will be 7,500 ft long and will have a maximum height of 157 ft above the stream bed with a maximum base width of 1,640 ft. The reservoir to be created will impound 2,095,000 acre-ft of water at flood-control pool level (elevation 1,136**) and will cover an area of 53,000 acres.

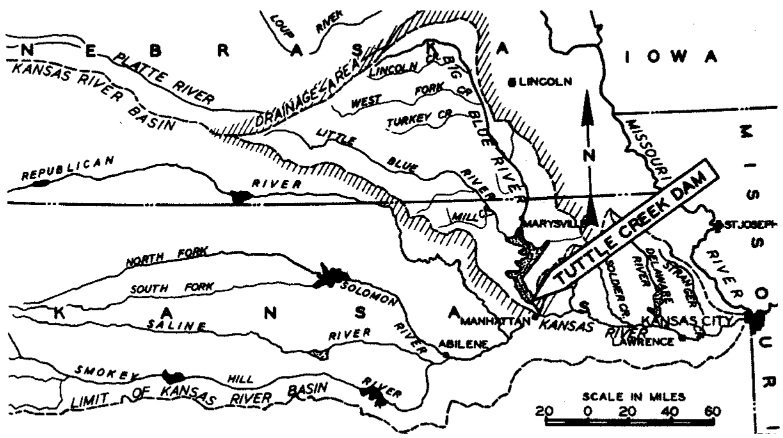


Fig. 1. Vicinity map

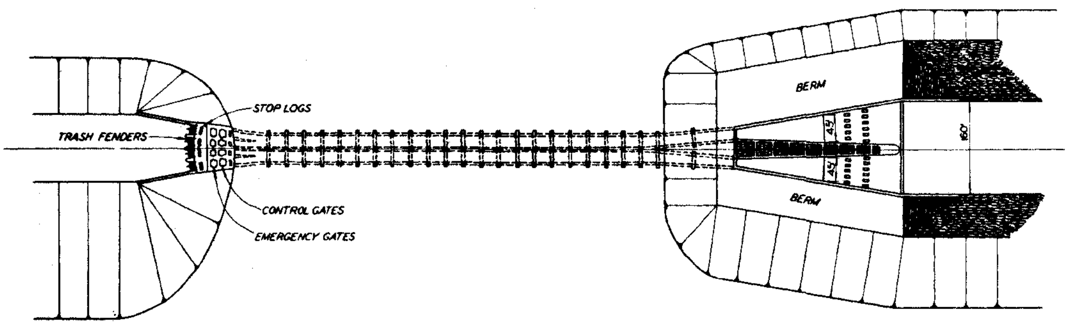
2. The spillway, located in the left abutment of the dam, will be of the chute type with an ogee crest at elevation 1,116. Flow will be controlled by twenty 40-ft by 20-ft tainter gates separated by 8-ft-wide piers. The spillway weir will have a gross length of 952 ft. It will be paved with concrete for 600 ft downstream from the center line of the

* Information obtained from "Definite Project Report, Tuttle Creek Dam and Reservoir, Big Blue River, Kansas."

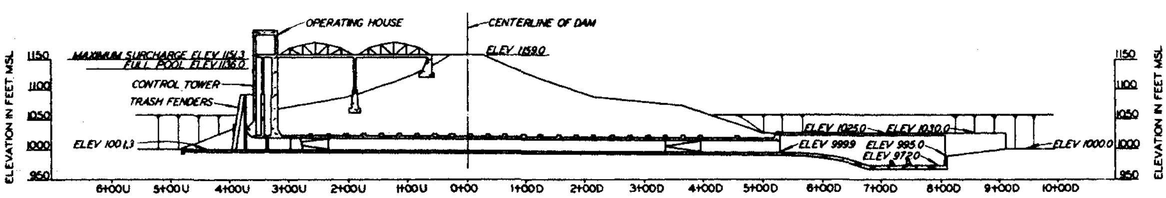
** All elevations are in feet above mean sea level.

crest, and will terminate in a flip bucket. Flow from the spillway will be returned to the Big Blue River by means of a combination outlet and pilot channel. The spillway is designed for a maximum discharge of 570,000 cfs at a pool elevation of 1,151.3.

3. The outlet structures, with approach and exit channels located in the valley on the right bank, will consist of an intake structure, twin horseshoe-shaped conduits and a stilling basin (fig. 2). The intake




PLAN OF OUTLET STRUCTURES




LONGITUDINAL SECTION THROUGH OUTLET STRUCTURES

Fig. 2. Outlet structures, plan and section

structure (plate 1) will be provided with trash fenders, and four fixed-wheel, tractor-type control gates, each 10 ft wide by 20 ft high, with upstream seals. These gates will be operated by hydraulically driven pistons and will be used for flood-control releases and stream-flow regulation. The roof of the intake is to be shaped to a quarter ellipse following the equation $\frac{X^2}{(20)^2} + \frac{Y^2}{(10)^2} = 1$ , while the side curve is to be shaped to the equation $\frac{X^2}{(8)^2} + \frac{Y^2}{(2.5)^2} = 1$ . The main barrel of the conduit will consist of twin 20-ft-diameter concrete conduits with transition sections near their upstream ends. The alignment of the twin

conduits will diverge about 200 ft from the outlet to accommodate a stilling basin divided into two sections. A downstream transition was originally proposed for the conduits to change the horseshoe shape of the conduits proper to a rectangular-shaped section 16 ft wide by 20 ft high for the remainder of the distance (123 ft) to the outlet portal. The over-all length of the conduits will be 915 ft, portal to portal.

4. In the selection of the size of the flood-control outlets, it was considered desirable to provide sufficient capacity to empty the recommended storage area (2,095,000 acre-ft) in a period of 40 days without exceeding bankful capacity of the Big Blue River. The 20-ft conduits were designed to have a combined discharge capacity of 45,000 cfs at maximum flood-control pool elevation 1,136; this capacity would be reduced to 29,000 cfs at maximum sedimentation pool elevation 1,061.

5. The stilling basin as originally designed was of the hydraulic-jump type. It was 290 ft long, and consisted of a 140-ft-long sloped section extending from the conduit exit to a horizontal apron 150 ft long. Stilling basin elements included two rows of 8.5-ft-high baffle piers, a stepped end sill 23 ft high, and parallel side walls which extended into the exit channel for a distance of 100 ft (fig. 7, page 16, and plate 11). The sloping apron followed the trajectory of a jet ($X^2 = 691\ Y$) of initial velocity 1.5 times the conduit exit velocity for a discharge of 22,500 cfs (the capacity of one conduit). The horizontal apron was at elevation 972.0; this elevation is 100 per cent of the theoretical depth (48 ft) required for the formation of a hydraulic jump at a discharge of 22,500 cfs. The basin was divided by a wall into two uniform sections, each section increasing in width from 16 ft at the conduit exit to 73 ft at the end sill. The stepped end sill had a top elevation of 995 (top of firm limestone). The outlet channel, with a base width of 160 ft, will carry the water from the stilling basin to the Big Blue River approximately 3,400 ft below the dam.

## Purpose of Model Analysis

6. Model tests of Tuttle Creek Dam were proposed because the

performance of some elements in the design could not be predicted by analytical means. The general purpose of the model studies was to analyze the hydraulic characteristics of all elements of the flood-control outlet structures and to develop means of correcting unsatisfactory conditions that might be found. The information desired required study of over-all performance of the structures, determination of the magnitude of forces acting on the control gate, investigation of cavitation tendencies at the gate slot, and observation of flow conditions in the downstream conduit transitions and stilling basin to determine how they might be affected by unsymmetrical inflow into the basin imposed by the curvature in the downstream portions of the conduits.

# PART II: THE MODEL

## Description

7. The model (fig. 3 and plate 2) was built to an undistorted scale ratio of 1:25, and reproduced about 75 ft of the approach area, the right half of the intake structure including two control gates, the intake transition, the twin horseshoe-shaped conduits, stilling basin with dividing wall, and about 500 ft of the exit channel. The left half of the intake and transition was simulated in sheet metal. A single slide gate permitted the introduction of the desired discharge into the left conduit.

8. The reservoir area was represented by a reinforced concrete headbay equipped with baffles to insure tranquil flow conditions. The floor of the approach area was molded in cement mortar. The right half

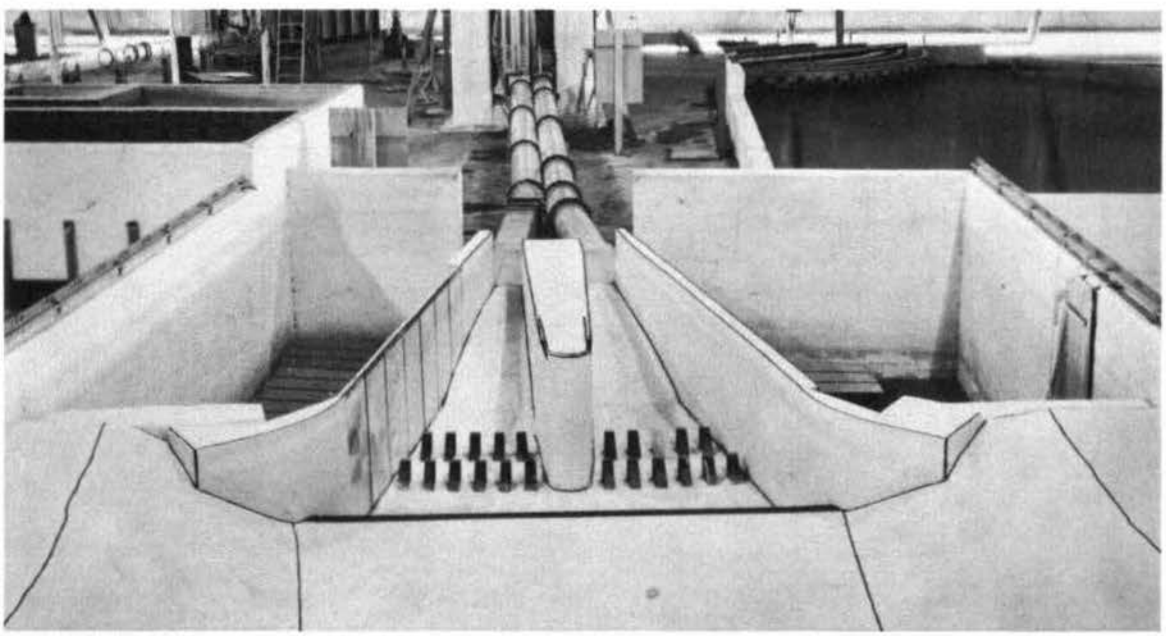


Fig. 3. The model

of the intake structure (fig. 4), transitions, and twin conduits were fabricated of transparent plastic to permit direct observation of flow conditions.

9. One tractor-type control gate was fabricated of plastic in

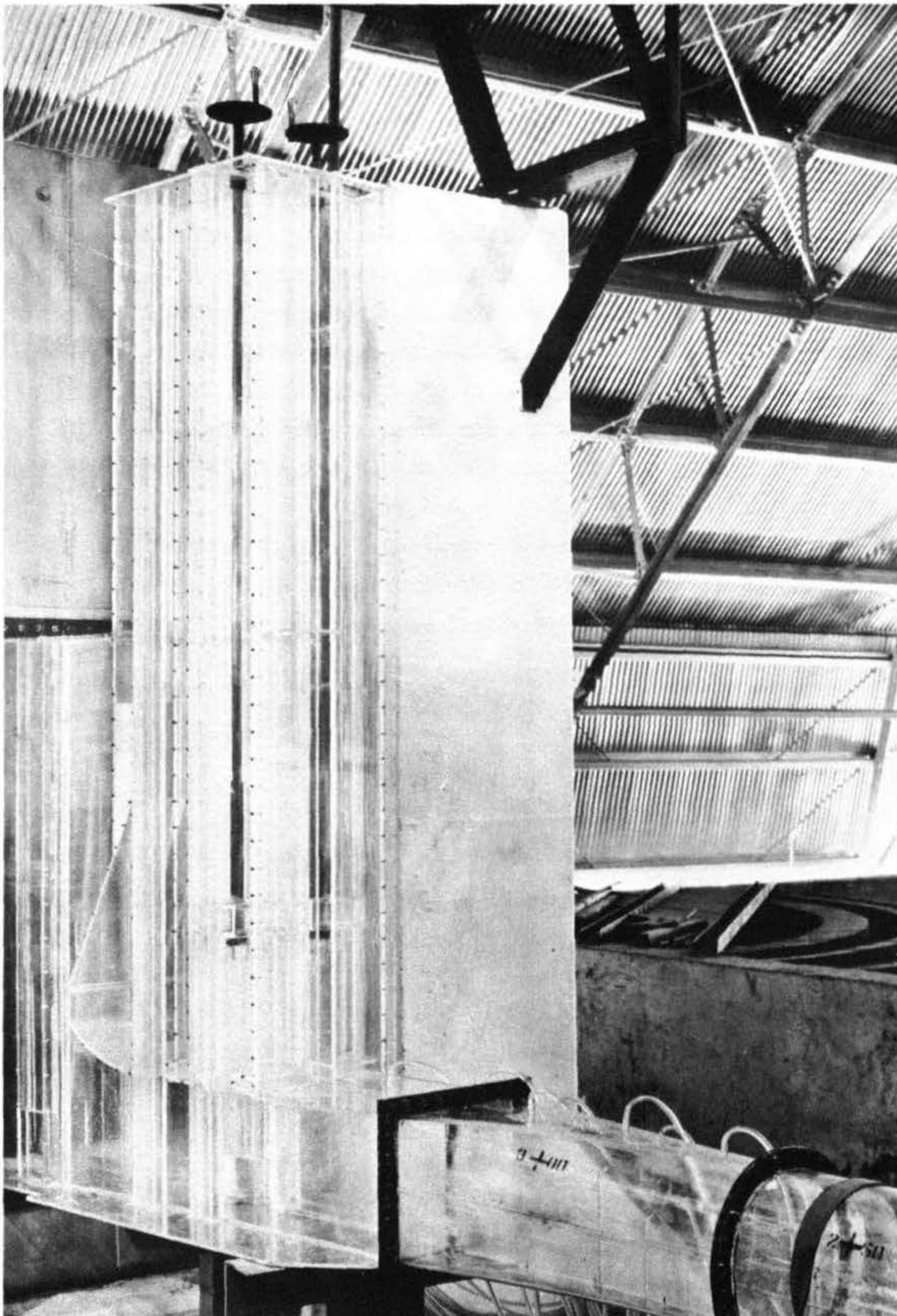


Fig. 4. Right half of intake structure

considerable detail in order that it would be geometrically similar to the prototype in weight, shape, and size so that forces acting on the gate might be accurately measured. The other control gate in the portion of the intake reproduced was fabricated of plastic in less detail but with gate and gate lip properly simulated to insure accurate discharge and pressure measurements.

10. The stilling basin, side walls, and basin elements were built of wood, with the exception of a transparent plastic section in the right basin wall, which permitted direct observation and the photographing of basin action. The exit area was molded in sand for erosion tests, and was capped with cement mortar for measurement of velocities. The downstream ends of the conduits, the stilling basin, and the exit channel were contained in a reinforced-concrete flume 41.5 ft long by 15.5 ft wide and 5.6 ft high (fig. 3 and plate 2).

11. Steel rails set to grade along each side of the model stilling basin and exit channel provided a reference plane for all measuring equipment. Water-surface elevations were measured by means of a portable sounding rod placed on an aluminum channel supported by the rails. Velocities were measured with a pitot tube so constructed as to permit measurements for any direction of flow. Flow conditions were recorded photographically. Pressures were measured by means of piezometers installed in the model and connected to a manometer board. Forces were measured on the test gate by means of a force indicator (fig. 5) graduated in tenths of a pound and

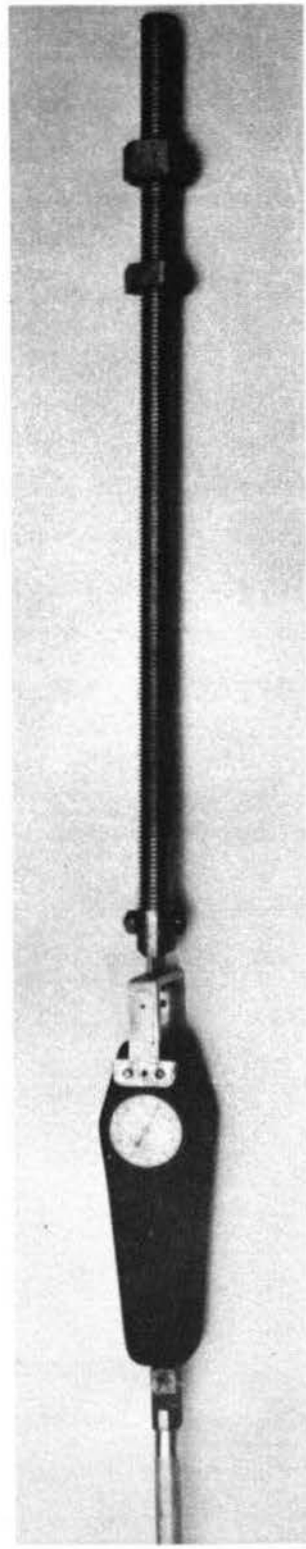


Fig. 5. Force indicator

accurate to the nearest tenth of a pound.

12. Water used in the operation of the model was supplied by a circulating system, the measurement of discharge being accomplished by use of venturi meters installed in the inflow lines. The tailwater elevations in the exit area were controlled by an adjustable tailgate. After passing over the tailgate, the water flowed through a return line back to the sump from which it was originally pumped.

## Scale Relationships

13. The accepted equations of hydraulic similitude, based upon the Froudian relationships, were used to express mathematical relationships between the dimensions and hydraulic quantities of the model and the prototype. General relationships for transference of model data to prototype equivalents, or vice versa, are presented in the following tabulation.

| Dimension | Ratio | Scale Relationships |
|---|---|---|
| Length | $L_r = L$ | 1:25 |
| Area | $A_r = L_r^{2}$ | 1:625 |
| Velocity | $V_r = L_r^{1/2}$ | 1:5 |
| Discharge | $Q_r = L_r^{5/2}$ | 1:3,125 |
| Roughness | $N_r = L_r^{1/6}$ | 1:1.710 |
| Force | $F_r = L_r^{3}$ | 1:15,625 |

## Interpretation of Model Results

14. Measurements of discharge, water-surface elevations, and velocities can be transferred quantitatively from model to prototype by means of the above scale relationships. Evidence of scour in the model is to be considered only qualitatively reliable, since it has not yet been found practicable to reproduce quantitatively in a model the resistance to erosion of a prototype bed material. The data on scour

tendencies provide a basis for resolving the question as to relative effectiveness of types and placements of basin elements, and indicate areas most subject to attack. Determination of the actual depth of scour to be expected in the prototype should be predicated upon the magnitude of bottom velocities and the characteristics of the prototype bed material.

# PART III: TESTS AND RESULTS

## Intake Structure

15. Tests of the intake structure involved observations of flow conditions, establishment of head-discharge relations for various combinations of gate openings, measurement of pressures, and determination of hydraulic forces acting on the test gate. These tests were made in the two passages leading to the right conduit as only the right half of the intake was reproduced in the model (see paragraph 7).

### Flow conditions

16. The streamlined entrance to each of the gate passages provided a smooth transition of flow with little or no disturbance.

### Head-discharge relationships

17. The control gates were calibrated to determine pool-discharge relationships for various combinations of full and partial gate openings (plates 3 and 4). These tests indicated a pool elevation of 1,131 for the maximum expected discharge of 22,500 cfs through one conduit with full gate opening; the computed pool elevation for passage of this flow was 1,136.

### Pressures

18. Pressures were measured in the intake for the following conditions of gate operation: (a) both gate passages fully open for a complete range of discharges; (b) left gate passage partially open with the right passage fully open and with the right passage closed; and (c) both gate passages partially open (equal openings). Piezometer locations are shown on plate 5. Pressures recorded are listed in tables 1-5. Favorable pressure conditions prevailed throughout the intake proper for all conditions tested and indicated the adequacy of the original intake design and shape of entrance curves.

19. In an effort to provide optimum pressure conditions at the gate slot, the original slot design was tapered on the downstream side (plate 6). Average pressures measured in the right passage with the left passage fully open, partially open, and closed are shown in tables 6 and 7.

Piezometers were located in the downstream tapered area of the gate slot in the right wall of the conduit (plate 6). Pressures were positive (above atmospheric) for all conditions tested. Gate slot pressure data must be qualified, however, because positive boundary pressures do not prove conclusively that a gate slot will be free of cavitation. Investigations of a similar gate slot shape (Bull Shoals) having a tapered downstream edge revealed positive boundary pressures in an atmospheric model; however, when the same shape was tested under subatmospheric conditions (which more closely approximated prototype conditions) the existence of cavitation was demonstrated in the flow away from the boundary with collapse of the cavitation bubble occurring downstream in a zone of high pressure. Prototype experience at Bull Shoals Dam has since substantiated this possibility in that slight cavitation damage on the tapered areas has been noted. The tapered-type slot, however, is currently the best means of alleviating cavitation damage at gate slots. Also, the use of upstream seals at Tuttle Creek should provide additional air at the gate slots at partial gate openings which will reduce cavitation tendencies.

20. Pressures also were measured on the upstream and downstream sides of the gate well to determine if the gate showed any tendency to move upstream at full and nearly full gate openings. Previous experience had indicated that gates with upstream seals tended to move upstream when raised to the fully open position. The resulting force was estimated to be of sufficient magnitude to damage the seals in the prototype. Upstream movement of the control gate at the fully open position was not detected on the Tuttle Creek model. Pressures recorded in the gate well are listed in table 8. At full gate opening and at pool elevation 1,140 the pressure in the gate well on the downstream side of the gate was as much as 2.3 ft higher than the pressure on the upstream side. Thus, there was a static head differential which would tend to move the gate in an upstream direction. At an 18-ft gate opening pressures on the downstream side of the gate at elevation 1,027.6 exceeded those on the upstream side by as much as 9.5 ft. However, pressures on that portion of the gate which extends down into the conduit at partial gate openings

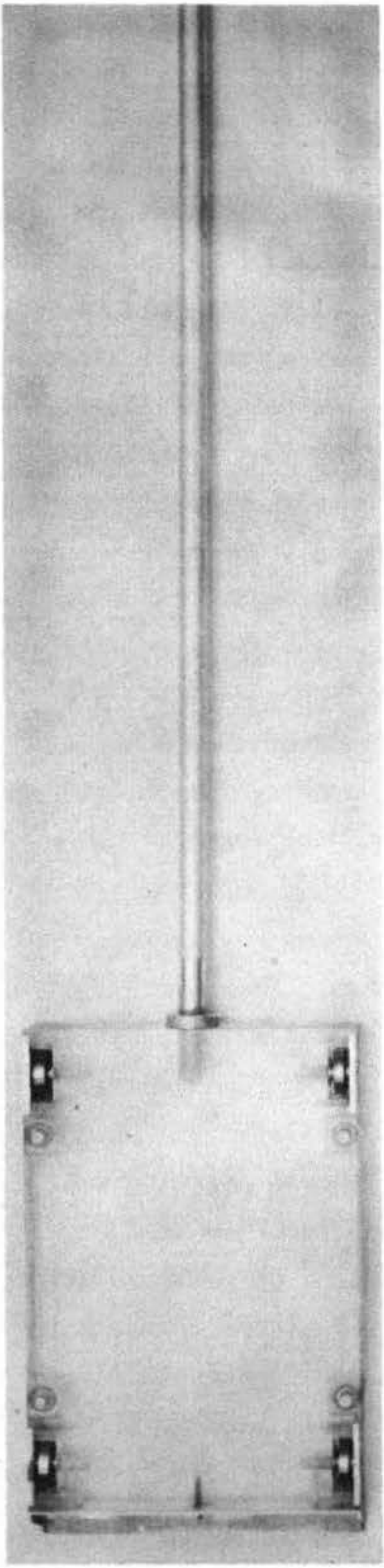


Fig. 6. Test gate

should be sufficient to overcome the head differential in the gate well.

Gate hoist requirements

21. The accurately reproduced test gate (paragraph 9) was located in the right passage of the original design conduit for all measurements. The test gate (fig. 6) was suspended on an aluminum stem which simulated the prototype hoist. This stem was fastened rigidly to the force indicator (fig. 5, page 7) which was held in position by an adjustable brass rod. The adjustable brass rod moved vertically in a collar and was used to fix the amount of gate opening as well as to keep the gate properly positioned. Prior to beginning a test the hoisting apparatus was inspected to preclude any excessive friction and to insure free movement of the bearings. The force indicator was carefully zeroed. All forces were measured with the gate set in a fixed position, since provisions were not made to study the gate in continuous operation.

22. Operating forces recorded at the various gate settings are shown on plate 7. The weight of the gate leaf was 25 tons. At small gate openings the only forces acting against the gate, in addition to its weight, were the uplift forces on the upstream seals. As the gate openings were increased the uplift forces were reduced and offset somewhat by a downward thrust resulting from leakage over the top of the gate. When the conduit flowed full, uplift forces were increased by the buoyancy of the gates; however, the gate wells were under

pressure for this condition of flow and the downward thrust on the top projection of the gates was increased. As the test gate did not reproduce all the exposed structural members, the submergence of the gate was noted in every instance and a correction was made for the actual buoyant force.

23. Measurements indicated that total downward forces ranging from 15 to 29 tons will be acting on the prototype hoist (plate 7). These forces are not excessive, inasmuch as the dry weight of the gate will be 25 tons.

## Intake Transition

### Flow conditions

24. Flow conditions in the transition from the twin passages of the intake structure to the horseshoe-shaped conduit 61 ft downstream were good. The sloped dividing pier separating the two passages provided a smooth junction of flow from each passage.

### Pressures

25. Pressure measurements were positive (above atmospheric) except for a few conditions where the amount of flow was insufficient to create any back pressure in that particular area (tables 1-5). Piezometer 55 read -9.2 ft with the right gate passage closed and the left gate passage fully open; also, with the right gate passage one-fourth open and the left gate passage fully open the same piezometer read -8.6 ft. Pressure gradients for most of the conditions tested are shown on plate 8. The gradients do not indicate any unfavorable characteristics in the design of the transition section.

## Conduit

26. Tests of the horseshoe-shaped conduit were limited to observations of flow conditions and pressure measurements. Flow appeared to be satisfactory for most conditions. Least desirable conditions were noted with one gate passage operating and at some partial gate

openings when flow was deflected back and forth across the conduit and was superelevated at various locations. The best flow conditions were found to obtain when both gate passages were operated at the same opening so that flow was equal in both passages. Pressure measurements are shown in tables 1-5 and piezometer locations are shown on plate 9.

## Outlet Transition

### Right conduit

27. Initially, tests were confined to the outlet transition in the right conduit. This transition (plate 9) from the horseshoe-shaped conduit to a rectangular shape 16 ft wide by 20 ft high was accomplished in a distance of about 61 ft and started about 123 ft upstream from the outlet portal. Pressure measurements are shown in tables 1-5, and piezometer locations in the outlet transition and rectangular section downstream are shown on plate 9. Studies of the transition and rectangular section were concerned with the deflection of flow and extent of superelevation that resulted at partial gate openings when the conduit was not flowing full. Observations also were made to determine the influence of the outlet transition on distribution of flow in the stilling basin. Generally, balanced flow conditions in the stilling basin resulted (photographs 1, 3, and 4).

### Left conduit

28. Although the outlet transition and rectangular section extending to the outlet portal produced satisfactory flow conditions in both the transition and the stilling basin, considerable objection was raised to the expense and difficulties that would be involved in construction. Therefore, the left conduit was installed with the horseshoe shape maintained throughout the entire conduit length (plate 10). The same curved alignment used in the right conduit was followed, although the width of the portal at the entrance to the stilling basin had to be increased by 4 ft to accommodate the 20-ft conduit. This procedure permitted a direct comparison of the performance of the two types of outlets.

29. Flow conditions. At partial gate openings there was some

superelevation of flow in the horizontal curve of the left conduit but distribution in the stilling basin appeared to be satisfactory. Dissipation of energy of flow from the left conduit compared favorably with that from the right conduit; this was also true with the stilling basin apron raised 5 ft as described in paragraph 40 (photographs 2 vs 1 and 10 vs 11.)

30. Stilling-basin performance. During the tests of the stilling basin, which are discussed in the paragraphs which follow, it was noted that basin performance was about the same downstream from either the right or left conduit. Water-surface profiles and bottom velocities for the two conduits may be compared by examining plates 13 and 21, 16 and 22, and plates 26 and 27. Comparison of scour measurements in the exit channel may be made by reference to plates 30 and 31. All data indicate that the type of outlet transition had little or no effect on basin performance.

## Original Design Stilling Basin

### Test conditions

31. Model investigations of the stilling basin (plate 11) involved observation of flow conditions, measurement of water-surface profiles, measurement of bottom velocities and velocities in a vertical plane to determine their magnitude and distribution, and the determination of erosion tendencies in the exit channel. Velocities usually were measured upstream of the first row of baffle piers, at the end sill, and in the exit channel. Pressures were measured on the center pier in the first row of baffle piers to determine possible cavitation tendencies. All tests were conducted with tailwater elevations adjusted in accordance with the data shown on plate 12; model tests were conducted, in most instances, for minimum tailwater conditions. Initial tests of the stilling basin were conducted with flow into only the right portion of the basin downstream from the rectangular-shaped outlet portal (fig. 7). In one series of tests the baffle piers were removed from the basin so that basin action without the piers could be determined.

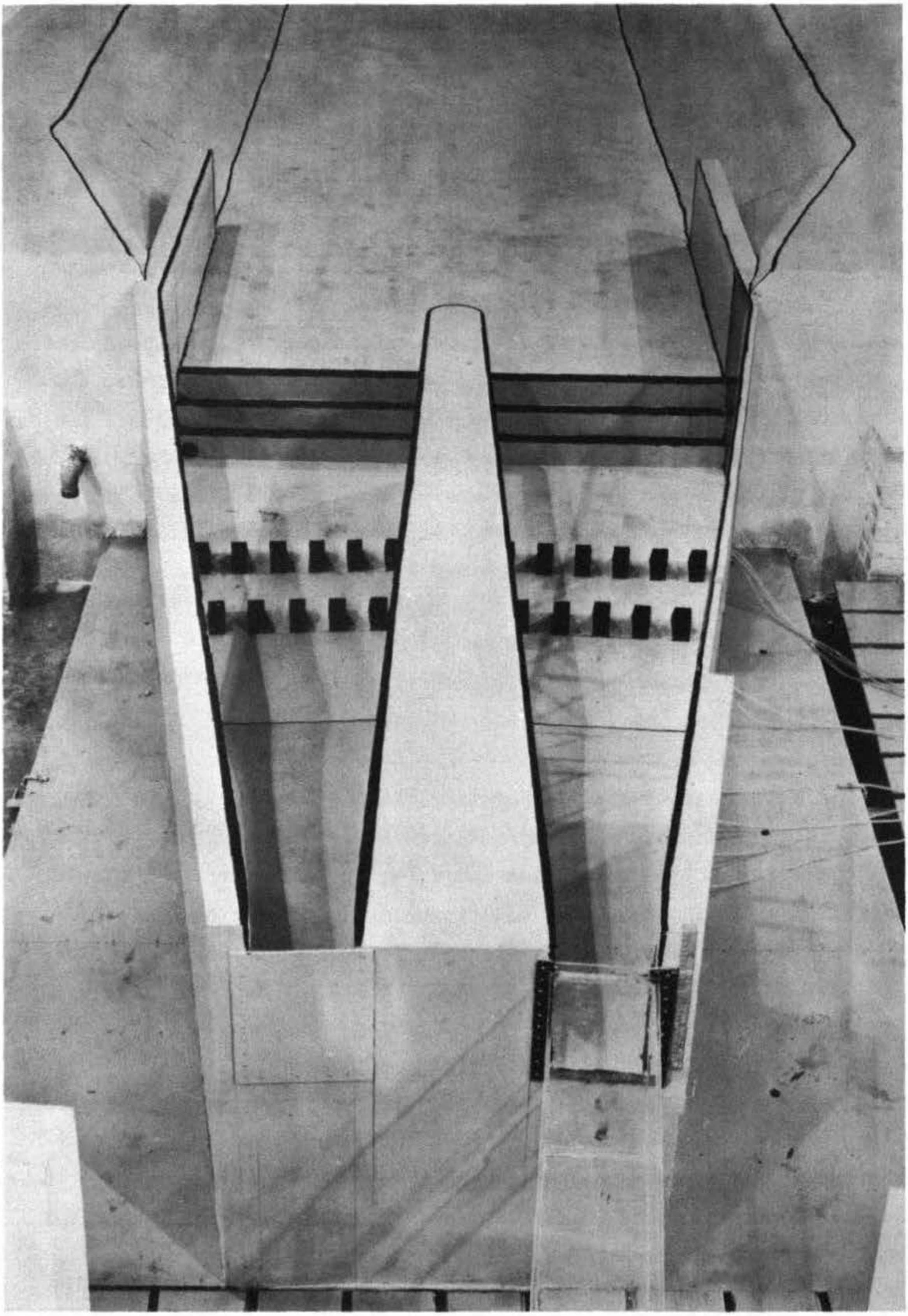


Fig. 7. Original design stilling basin

Single conduit operation

32. Flow conditions. Flow conditions in the stilling basin with the right conduit operating are shown in photographs 1 and 3-7. Hydraulic jump action for the maximum discharge of 22,500 cfs (photographs 1 and 5) was good and all flow appeared to be evenly distributed across the end sill. Observation of flow conditions through the plastic viewing window revealed that the upstream row of baffle piers was subjected to high velocities. All high velocity traces appeared to be deflected upward toward the surface by the first row of baffle piers, and impact of flow on the second row of baffles appeared to be slight. For all discharges the toe of the hydraulic jump was located over the curved portion of the apron. As the discharges were reduced below 22,500 cfs flow action within the basin and downstream became more tranquil. For discharges of 15,000 cfs and less all turbulence in the basin was confined to the area near the junction of the curved and horizontal aprons. The side walls of the basin appeared to be of adequate height to prevent overtopping.

33. Velocity measurements. Plates 13-18 show velocity measurements recorded in and downstream from the stilling basin for discharges of 22,500, 20,000, and 15,000 cfs from the right conduit only. For a discharge of 22,500 cfs maximum bottom velocities ranged from 48 fps at the first row of baffle piers to 11 fps in the exit channel. Surface velocities, at the same locations and discharge, ranged from 53 fps to 14 fps. Velocities immediately over the end sill were negligible. The magnitude of all velocities decreased as the discharge was reduced. Measurements of velocities over vertical planes at various locations (plates 16-18) indicated good distribution of flow within the stilling basin; velocities in the exit area tended to be greater along the right bank. The removal of the baffle piers from the stilling basin revealed an appreciable increase in surface velocities at the end sill and in the exit area for maximum discharge conditions (plate 19). At a discharge of 15,000 cfs, velocities were increased only slightly by removal of the baffle piers (plate 20). Removal of the baffle piers also tended to impair the basin performance noted previously (photographs 8 and 9).

34. Water-surface profiles. Water-surface profiles through the

stilling basin are shown on plates 13-15 and indicate the adequacy of the side walls to contain flow. A freeboard of about 5 ft existed at the maximum discharge.

35. Left conduit. Following tests of single conduit operation with the right conduit operating, the left conduit was installed as described in paragraph 28 and basin performance observed. The data obtained were similar to those recorded with the right conduit operating (see photograph 2 and plates 21 and 22).

Twin conduit operation

36. Flow conditions. Flow conditions in the basin with both conduits in operation providing a total discharge of 45,000 cfs (22,500 cfs from each conduit) are shown in photograph 10. Good hydraulic jump action existed in each portion of the stilling basin and flow appeared to be uniformly distributed as it entered the exit area. A slight amount of overtopping occurred at the downstream end of the central dividing wall.

37. Velocity measurements. Velocities recorded for twin conduit operation are shown on plates 23 and 24. The discharge of 45,000 cfs and the resulting higher tailwater elevation reduced maximum bottom velocities at the first row of baffle piers to 39 fps; bottom velocities in the exit area were still in the range of 11 fps, as they were for single conduit operation. Velocity distribution over the end sill and in the exit area was uniform.

38. Water-surface profiles. Water-surface profiles in each portion of the stilling basin are shown on plate 23. These data indicate almost identical profiles in each basin. The data also indicate that the maximum average water-surface elevation is about the same (elevation 1,025) as the elevation of the central dividing wall.

39. Scour. Results of an erosion test conducted with flow from both conduits (plate 25) revealed that the areas of greatest scour were adjacent to the side walls and in the center of the exit area immediately downstream from the dividing wall. Some erosion was noted immediately downstream from the end sill, however, the deepest scour hole was located about 50 ft downstream from the sill.

## Alterations to the Original Stilling Basin Design

### Horizontal apron elevation

40. As stated in paragraph 5, the original apron elevation of 972 was based on the full theoretical jump depth of 48 ft for a discharge of 22,500 cfs and a tailwater elevation of 1,020; minimum tailwater elevation for a discharge of 22,500 cfs is 1,017. In view of the excellent basin performance obtained with the original design, it appeared that the apron elevation might be raised (decrease the tailwater depth) without impairing basin performance. Accordingly the apron elevation was raised 5 ft to elevation 977 ($0.9D_2$). In raising the apron elevation the baffle piers were moved upstream to stations 6+61.4 and 6+96.4 which maintained the piers in about the same relative position with respect to the junction of the horizontal and sloped aprons. The end sill was not moved. These changes, in effect, lengthened the horizontal apron about 12.6 ft. Test results indicated that the baffle piers were too close to the toe of the sloped apron. The 5-ft decrease in tailwater resulted in velocity measurements at the baffle piers in the range of 60 fps; however, jump action was satisfactory and was confined to the basin proper (photographs 11-12).

### Location of baffle piers

41. To reduce the impact on the upstream row of baffle piers, the two rows were located at stations 6+85.4 and 7+15.4 and at stations 6+76 and 7+06, the original locations. The apron elevation of 977 was maintained. It was determined from a short series of observation tests that two rows of baffle piers located at stations 6+76 and 7+06 provided optimum flow conditions (photographs 13-14).

### Alternate basin design 1

42. To fully evaluate the revisions previously discussed, detailed stilling basin tests were conducted with the apron at elevation 977 and 8.5-ft-high baffle piers located at stations 6+76 and 7+06.

43. Flow conditions. Flow conditions, observed in the stilling basin as revised for conditions of single and twin conduit operation, were satisfactory (photographs 14 and 15).

44. Velocity measurements. Sectional velocity measurements, made

at various locations in and downstream from the stilling basin, are shown on plates 26-28. Comparison of these data with data obtained with the stilling basin at elevation 972 (plates 16 and 22) reveals that bottom velocities were of about the same magnitude and that surface velocities were slightly greater for the higher basin. Plates 24 and 33 afford a similar comparison for a discharge of 45,000 cfs (both conduits operating).

45. Scour. Erosion tests were conducted at a discharge of 45,000 cfs (twin conduit operation) and discharges of 22,500 cfs through each conduit (plates 29-31). All tests indicated that the areas subject to greatest attack were located adjacent to the wing walls. The right and left portions of the basin showed similar scour patterns for single conduit operation thus indicating that the type of outlet portal had little effect on basin performance. Scour data with both conduits discharging (plate 29) were almost identical with those recorded with the basin at elevation 972 (plate 25). Thus it appears that a basin at elevation 977 will perform satisfactorily in the prototype.

46. Impact on baffle piers. Velocities measured in the vicinity of the upstream row of baffle piers are presented, as stated previously, on plates 26 and 27. Computations indicate that for a velocity as high as 50 fps a force of 54 tons on the face of the pier might be expected. Pressures were measured on the center pier in the front row of baffle piers (station 6+76) in the left stilling basin. Piezometer locations are shown on plate 32 and the average pressures recorded are presented in table 9. For discharges of 15,000 cfs and less, all average pressures were positive (above atmospheric); for discharges of 20,000 and 22,500 cfs minimum pressures of -18.6 and -25.6 ft, respectively, were recorded. Prediction of cavitation damage to a prototype structure based on average model pressure measurements is uncertain. This is particularly true in an area where pressure fluctuations are large, as in a hydraulic jump-type stilling basin. On the basis of tests previously conducted at the Waterways Experiment Station*, it is believed that the upstream row of

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* Waterways Experiment Station, A Laboratory Development of Cavitation-Free Baffle Piers, Bluestone Dam, New River, West Virginia, Technical Memorandum No. 2-243, March 1948.

baffle piers at Tuttle Creek can be expected to sustain slight cavitation damage at a single conduit discharge of 20,000 cfs, and increased damage at a discharge of 22,500 cfs.

Effect of end sill and exit channel elevation

47. The end sill and exit channel were lowered to investigate the possibility of improving flow conditions in the exit area. Tests were conducted with (a) the end sill and exit area at elevation 995, (b) the end sill at elevation 990 and the bed of the exit sloped to elevation 995 in a distance of 100 ft, and (c) the end sill and exit area at elevation 990.

48. Velocity measurements. As was to be expected, velocities in the exit area were decreased by a reduction in elevation of the exit area (plates 33 and 34). Velocities were reduced almost 50 per cent by lowering the exit area from elevation 1,000 (original) to 990. For intermediate elevations between 1,000 and 990, velocities were also lower than those observed with the exit area at elevation 1,000.

49. Scour. Measurements of scour resulting from the discharge of 45,000 cfs from both conduits were similar with the exit area at either elevation 995 or 990 (plates 35 and 36). Comparison of these data with scour data obtained with the exit area at elevation 1,000 (plate 29) indicates similar results. Thus it appears that the exit area will erode to about the configuration shown on the referenced plates after which the bed will become stabilized.

Effect of shortening center dividing wall

50. The center dividing wall in the stilling basin extended to station 7+67. In an effort to effect construction economies, the wall was shortened 91 ft (station 6+76), 50 ft (station 7+17), and 30 ft (station 7+37) and the effect on basin performance observed. Flow conditions for single conduit operation were unsatisfactory with the downstream portion of the wall extending only to station 6+76 (first row of baffle piers, see photographs 16 and 17). Eddies developed and caused high velocities adjacent to the side walls of the basin. Further investigations with the

wall shortened 30 and 50 ft in successive tests revealed that the wall could be shortened about 50 ft without affecting basin performance for either twin or single conduit operation (photographs 18-20 and plate 37). Erosion tests also indicated that shortening of the dividing wall was permissible. Scour measured after tests with both conduits discharging was identical with that measured after similar tests with the original wall. For single conduit operation, scour immediately downstream from the sill was about the same for both walls, although some eddy action developed with the shorter wall which moved material upstream onto the apron of the nonoperating basin (compare plates 30 and 38).

Effect of shortened basin length

51. Observation of flow conditions in the stilling basin indicated the possibility of reducing the length of the apron between the second row of baffle piers and the end sill. This portion of the basin was shortened 15 and 30 ft in successive tests and basin performance observed; the dividing wall was terminated at station 7+17. Observation of flow conditions (photographs 21-23) did not reveal appreciable effect on basin performance as a result of a 30-ft reduction in length. Velocities in the exit area were not affected appreciably by the shortened basin; however, surface velocities in the vicinity of the end sill were almost doubled (plate 39). Scour downstream from the end sill was also increased slightly. Therefore, it was decided to maintain the original basin length.

Recommended stilling-basin design

52. Details of a stilling-basin design incorporating the most desirable features investigated during the course of the model tests are shown on plate 40; this design is recommended for construction. It includes the basin at elevation 977 and the center dividing wall shortened 50 ft to station 7+17. Also, on the basis of previous model studies conducted at the Waterways Experiment Station, the parallel wing walls extending 100 ft downstream from the end sill were replaced with walls curved on a 58-ft radius (fig. 3, page 5).

53. Flow conditions. Flow conditions for single and twin conduit operation are shown on photographs 24-29. Flow appeared to be evenly

distributed as it entered the exit area for twin conduit flow. The center dividing wall and curved side walls downstream from the end sill did not impair flow conditions and should afford construction economies. For a discharge of 22,500 cfs from a single conduit the tailwater had to be lowered to elevation 1,011 (plate 12) before the jump was lost from the stilling basin. Elevation 1,011 is 6 ft lower than the tailwater elevation expected after ultimate retrogression.

54. Velocity measurements. The magnitudes of velocities over the end sill and in the exit area are presented on plates 41 and 42. Bottom velocities were highest for single-conduit operation and were as high as 10 fps; for twin-conduit operation maximum bottom velocities were about 8 fps. The curved wing walls resulted in a reduction in bottom velocities below those observed with the parallel walls.

55. Scour. The results of scour tests (plates 43 and 44) indicated a considerable reduction in scour adjacent to the wing walls. Scour in the center of the exit area was about the same as observed in previous tests.

## PART IV: DISCUSSION OF RESULTS

56. The results of the model investigations of the outlet structures proposed for Tuttle Creek Dam confirmed the adequacy of certain elements of the structures as designed and indicated the modification of other elements.

57. Flow conditions through the intake structure, upstream transition, and conduit were generally favorable for most operating conditions; however, it was observed that for partial gate openings best performance resulted with equal gate openings which provided balanced flow in the conduit. For most conditions positive pressures existed throughout except that a negative pressure of -9.2 ft was recorded at one point in the transition with a single gate at full opening. Over-all flow capacity of the structures was slightly in excess of that computed.

58. The service gate with upstream seals appeared to operate satisfactorily. No tendency was apparent in the model for the gate to move upstream as a result of unbalanced pressures in the gate well; an unbalanced pressure in the gate well of 9.5 ft in an upstream direction was recorded but it is believed to have been offset by pressures on the portion of the gate projecting into the flow. Maximum downpull forces exceeded the weight of the gate by only 4 tons.

59. Observations of flow conditions in the downstream portions of the twin conduits indicated that the transition and rectangular-shaped section to the outlet portal provided slightly improved hydraulic performance. Effect on stilling-basin action could not be detected, however, and it is believed that the extra expense involved in construction of the downstream transition is not warranted. Therefore, it is recommended that the conduits be extended to the outlet portals unchanged in cross section and shape.

60. Tests of the stilling basin demonstrated that although the original design was satisfactory, alterations could be made that would effect economies in construction without impairing basin performance. The stilling-basin design recommended for adoption is shown on plate 40, and modifies the original design by (a) raising the basin 5 ft to

elevation 977, (b) shortening the length of the center dividing wall 50 ft, and (c) substitution of curved wing walls. Some damage to the baffle piers through cavitation action might be sustained by prolonged operation of a single conduit at the maximum discharge of 22,500 cfs; however, no damage is expected from discharges of 15,000 cfs and below. To reduce possible damage to a minimum, it is recommended that special care be taken in the construction of the first row of baffle piers to insure a good quality of concrete.

Table 1

PRESSURES THROUGHOUT OUTLET STRUCTURES, ORIGINAL DESIGN

Two Gates Open Full

| Piez No. | Piez Station and Location | Piez Zero | Two Passages Right Conduit Open Full: Dischg, 22,500 Pool El, 1131.0 | Dischg, 20,000 Pool El, 1110.0 | Dischg, 15,000 Pool El, 1071.0 | Dischg, 10,000 Pool El, 1041.5 | Dischg, 5,000 Pool El, 1024.5 |
|---|---|---|---|---|---|---|---|
| 1 | 4+03.5 Roof | 1031.3 | 84.2 | 66.2 | 33.7 | 10.2 | * |
| 2 | 4+02.5 Roof | 1028.2 | 79.3 | 64.3 | 33.3 | 12.3 | * |
| 3 | 4+01.5 Roof | 1026.9 | 67.1 | 58.6 | 28.1 | 10.1 | * |
| 4 | 4+00.5 Roof | 1025.3 | 65.3 | 52.0 | 27.7 | 10.2 | * |
| 5 | 3+98.5 Roof | 1024.2 | 64.0 | 51.0 | 27.3 | 10.4 | * |
| 6 | 3+96.5 Roof | 1023.1 | 59.9 | 48.4 | 25.9 | 10.2 | * |
| 7 | 3+94.5 Roof | 1022.6 | 54.2 | 45.0 | 23.4 | 9.4 | * |
| 8 | 3+92.5 Roof | 1022.1 | 53.4 | 43.3 | 23.4 | 9.4 | * |
| 9 | 3+90.5 Roof | 1021.8 | 51.7 | 42.2 | 22.7 | 9.9 | * |
| 10 | 3+88.5 Roof | 1021.5 | 49.8 | 40.5 | 22.0 | 9.6 | * |
| 11 | 3+86.5 Roof | 1021.4 | 49.6 | 40.6 | 22.1 | 9.1 | * |
| 12 | 3+84.5 Roof | 1021.3 | 53.2 | 44.7 | 23.7 | 9.7 | * |
| 13 | 4+03.5 Corner of Roof | 1031.3 | 84.2 | 67.2 | 33.7 | 10.2 | * |
| 14 | 4+02.5 Corner of Roof | 1028.2 | 81.5 | 64.8 | 33.8 | 12.3 | * |
| 15 | 4+01.5 Corner of Roof | 1026.9 | 67.1 | 53.6 | 29.1 | 10.7 | * |
| 16 | 4+00.5 Corner of Roof | 1025.3 | 65.5 | 52.5 | 28.2 | 10.7 | * |
| 17 | 3+98.5 Corner of Roof | 1024.2 | 64.6 | 51.3 | 28.3 | 11.0 | * |
| 18 | 3+96.5 Corner of Roof | 1023.1 | 60.1 | 48.4 | 26.9 | 10.5 | * |
| 19 | 3+94.5 Corner of Roof | 1022.6 | 54.7 | 45.4 | 24.7 | 9.9 | * |
| 20 | 3+92.5 Corner of Roof | 1022.1 | 53.1 | 42.9 | 24.2 | 9.6 | * |
| 21 | 3+90.5 Corner of Roof | 1021.8 | 50.7 | 41.2 | 23.2 | 9.2 | * |
| 22 | 3+88.5 Corner of Roof | 1021.5 | 49.5 | 40.2 | 22.7 | 9.0 | * |
| 23 | 3+86.5 Corner of Roof | 1021.4 | 49.8 | 40.8 | 22.8 | 9.1 | 0.6 |
| 24 | 3+84.5 Corner of Roof | 1021.3 | 54.7 | 44.9 | 24.7 | 10.0 | 0.7 |
| 25 | 3+74.5 Roof | 1021.3 | 56.0 | 45.7 | 27.7 | 10.3 | * |
| 26 | 3+49.5 Roof | 1021.3 | 56.7 | 46.2 | 25.2 | 9.7 | 0.2 |
| 27 | 3+29.5 Roof | 1021.3 | 56.2 | 45.9 | 23.2 | 9.7 | 0.2 |
| 28 | 4+29.0 Pier | 1011.3 | 110.0 | 91.2 | 55.0 | 28.2 | 10.9 |
| 29 | 4+27.0 Pier | 1011.3 | 111.2 | 92.2 | 55.2 | 28.2 | 10.9 |
| 30 | 4+23.0 Pier | 1011.3 | 112.2 | 93.3 | 56.0 | 28.3 | 11.2 |
| 31 | 4+15.0 Pier | 1011.3 | 111.7 | 92.7 | 55.0 | 28.9 | 11.7 |
| 32 | 4+09.0 Pier | 1011.3 | 107.7 | 89.5 | 53.5 | 28.3 | 11.7 |
| 33 | 3+98.5 Side | 1011.3 | 91.9 | 76.7 | 46.4 | 25.4 | 11.4 |
| 34 | 3+88.5 Side | 1011.3 | 74.4 | 62.2 | 39.2 | 22.1 | 10.9 |
| 35 | 3+74.5 Side | 1011.3 | 63.4 | 57.9 | 36.0 | 20.7 | 10.5 |
| 36 | 3+49.5 Side | 1011.3 | 67.2 | 56.5 | 35.2 | 20.2 | 10.2 |
| 37 | 3+29.5 Side | 1011.3 | 63.7 | 54.2 | 33.7 | 18.7 | 10.2 |
| 38 | 3+98.5 Invert | 1011.3 | 104.2 | 88.0 | 57.7 | 35.7 | 21.5 |
| 39 | 3+88.5 Invert | 1001.3 | 88.2 | 76.0 | 50.9 | 32.9 | 21.0 |
| 40 | 3+58.5 Invert | 1001.3 | 76.7 | 66.4 | 45.2 | 30.2 | 20.2 |
| 41 | 3+29.5 Invert | 1001.3 | 75.2 | 64.9 | 44.5 | 29.9 | 20.2 |
| | | | | Intake Transition | | | |
| 42 | 3+17.0 Invert | 1001.3 | 75.7 | 65.3 | 44.7 | 30.0 | 20.2 |
| 43 | 3+17.0 Left Fillet | 1001.8 | 76.2 | 65.7 | 44.7 | 29.8 | 19.7 |
| 44 | 3+17.0 Left Side | 1011.3 | 67.2 | 55.9 | 35.2 | 20.3 | 10.2 |
| 45 | 3+17.0 Left Fillet | 1020.5 | 58.3 | 47.5 | 16.5 | 10.0 | 0.7 |
| 46 | 3+17.0 Roof | 1021.3 | 55.5 | 45.2 | 24.3 | 9.7 | 0.3 |
| 47 | 2+97.4 Invert | 1001.3 | 66.5 | 58.0 | 40.7 | 28.2 | 19.9 |
| 48 | 2+97.4 Left Fillet | 1002.7 | 65.8 | 57.3 | 39.9 | 27.1 | 18.5 |
| 49 | 2+97.4 Left Side | 1011.3 | 57.5 | 48.9 | 31.2 | 18.5 | 9.9 |
| 50 | 2+97.4 Left Fillet | 1019.2 | 49.6 | 40.8 | 23.5 | 10.6 | 2.0 |
| 51 | 2+97.4 Roof | 1021.3 | 48.7 | 38.9 | 21.4 | 8.6 | * |
| 52 | 2+77.1 Invert | 1001.6 | 50.4 | 45.4 | 33.4 | 24.9 | 19.0 |
| 53 | 2+77.1 Left Fillet | 1003.0 | 50.8 | 44.8 | 32.7 | 23.9 | 17.6 |
| 54 | 2+77.1 Left Side | 1011.2 | 44.1 | 37.8 | 25.2 | 15.8 | 9.4 |
| 55 | 2+77.1 Left Fillet | 1018.7 | 34.3 | 28.8 | 16.6 | 7.9 | 1.9 |

(Continued)

See Notes at end of table.

Table 1 (Continued)

| Piez No. | Piez Station and Location | Piez Zero | Two Passages Right Conduit Open Full: Dischg, 22,500 Pool El, 1131.0 | Dischg, 20,000 Pool El, 1110.0 | Dischg, 15,000 Pool El, 1071.0 | Dischg, 10,000 Pool El, 1041.5 | Dischg, 5,000 Pool El, 1024.5 |
|---|---|---|---|---|---|---|---|
| | | | | Intake Transition (continued) | | | |
| 56 | 2+77.1 Roof | 1021.2 | 32.8 | 26.8 | 14.1 | 5.7 | * |
| 57 | 2+98.7 Pier | 1016.2 | 46.7 | 39.9 | 23.9 | 12.5 | 4.7 |
| 58 | 2+90.5 Pier | 1011.3 | 47.0 | 40.7 | 26.7 | 16.6 | 9.7 |
| 59 | 2+82.2 Pier | 1006.2 | 46.5 | 40.8 | 29.0 | 20.5 | 14.5 |
| 60 | 2+90.5 Left Side | 1011.3 | 52.7 | 44.9 | 29.2 | 17.4 | 9.9 |
| | | | | Horseshoe Conduit | | | |
| 61 | 2+50.0 Invert | 1001.2 | 49.8 | 44.5 | 33.0 | 24.8 | 19.5 |
| 62 | 2+00.0 Invert | 1001.1 | 46.4 | 41.4 | 31.4 | 24.2 | 19.4 |
| 63 | 1+00.0 Invert | 1000.9 | 40.6 | 37.1 | 28.9 | 23.3 | 19.3 |
| 64 | 0+00.0 Invert | 1000.8 | 37.9 | 35.2 | 27.4 | 22.7 | 19.2 |
| 65 | 1+00.0 Invert | 1000.6 | 32.4 | 29.9 | 25.0 | 21.9 | 19.2 |
| 66 | 2+00.0 Invert | 1000.4 | 30.1 | 28.3 | 24.1 | 21.4 | 19.1 |
| 67 | 3+00.0 Invert | 1000.2 | 24.8 | 24.4 | 21.8 | 20.3 | 18.8 |
| | | | | Downstream Transition | | | |
| 68 | 3+23.0 Invert | 1000.2 | 22.0 | 21.6 | 20.6 | 19.7 | 18.8 |
| 69 | 3+23.0 Left Fillet | 1001.8 | 22.7 | 21.7 | 19.7 | 18.4 | 17.2 |
| 70 | 3+23.0 Left Side | 1010.2 | 13.5 | 12.8 | 11.0 | 9.9 | 8.8 |
| 71 | 3+23.0 Roof | 1020.2 | 2.0 | 1.3 | 0.5 | -0.4 | -1.2 |
| 72 | 3+23.0 Left Side | 1010.2 | 11.4 | 10.8 | 10.3 | 9.4 | 8.8 |
| 73 | 3+23.0 Left Fillet | 1001.8 | 18.6 | 18.7 | 18.0 | 17.7 | 17.2 |
| 74 | 3+43.0 Invert | 1001.2 | 23.0 | 22.3 | 20.6 | 19.7 | 18.8 |
| 75 | 3+43.0 Left Fillet | 1001.1 | 24.4 | 22.9 | 20.8 | 19.3 | 18.9 |
| 76 | 3+43.0 Left Side | 1010.2 | 13.0 | 12.3 | 11.0 | 9.8 | 8.8 |
| 77 | 3+43.0 Roof | 1020.2 | 3.0 | 1.8 | 0.7 | -0.2 | -1.2 |
| 78 | 3+43.0 Right Side | 1010.2 | 13.2 | 12.3 | 11.0 | 9.8 | 8.8 |
| 79 | 3+43.0 Right Fillet | 1001.1 | 21.3 | 20.4 | 19.4 | 18.6 | 17.9 |
| 80 | 3+63.0 Invert | 1000.1 | 19.4 | 19.9 | 19.4 | 19.3 | 18.9 |
| 81 | 3+63 Left Fillet | 1000.5 | 20.3 | 20.0 | 19.3 | 19.1 | 18.5 |
| 82 | 3+63 Left Side | 1010.1 | 10.8 | 10.4 | 9.9 | 9.5 | 8.9 |
| 83 | 3+63 Roof | 1020.1 | 1.4 | 0.9 | 0.2 | -0.4 | -1.1 |
| 84 | 3+63 Right Side | 1010.1 | 7.7 | 8.4 | 8.4 | 8.9 | 8.9 |
| 85 | 3+63 Right Fillet | 1000.5 | 16.0 | 17.3 | 17.7 | 18.4 | 18.1 |
| | | | | Rectangular Conduit | | | |
| 86 | 4+00 Invert | 1000.1 | 13.4 | 15.9 | 16.6 | 18.1 | 14.9 |
| 87 | 4+90 Invert | 999.9 | 8.1 | 10.7 | 13.9 | 16.3 | 12.6 |

Notes: Pressures are recorded in prototype feet of water.
Discharges are recorded in cubic feet per second.
Pool elevations are recorded in feet above mean sea level.
All pressure measurements confined to right half of outlet structures.
*Piezometer is above water surface.

## Table 2

PRESSURES THROUGHOUT OUTLET STRUCTURES, ORIGINAL DESIGN

Two Gates Partially Open

| Piez No. | Piez Station and Location | Piez Zero | Both Gate Passages 3/4 Open: Dischg, 19,500 Pool El, 1140.0 | Both Gate Passages 3/4 Open: Dischg, 17,000 Pool El, 1110.0 | Both Gate Passages 3/4 Open: Dischg, 12,800 Pool El, 1071.0 | Both Gate Passages 1/2 Open: Dischg, 12,375 Pool El, 1140.0 | Both Gate Passages 1/2 Open: Dischg, 10,850 Pool El, 1110.0 | Both Gate Passages 1/2 Open: Dischg, 8,400 Pool El, 1071.0 |
|---|---|---|---|---|---|---|---|---|
| 1 | 4+03.5 Roof | 1031.3 | 96.4 | 70.2 | 35.8 | 104.5 | 75.5 | 37.9 |
| 2 | 4+02.5 Roof | 1028.2 | 93.3 | 68.8 | 36.5 | 105.4 | 76.8 | 39.7 |
| 3 | 4+01.5 Roof | 1026.9 | 85.3 | 62.5 | 32.6 | 102.4 | 75.2 | 38.8 |
| 4 | 4+00.5 Roof | 1025.3 | 84.5 | 62.0 | 33.0 | 102.7 | 76.1 | 39.8 |
| 5 | 3+98.5 Roof | 1024.2 | 84.0 | 61.8 | 33.2 | 103.2 | 76.4 | 40.7 |
| 6 | 3+96.5 Roof | 1023.1 | 81.6 | 60.4 | 32.6 | 102.9 | 76.4 | 41.2 |
| 7 | 3+94.5 Roof | 1022.6 | 77.2 | 56.9 | 31.2 | 101.7 | 75.8 | 40.9 |
| 8 | 3+92.5 Roof | 1022.1 | 77.4 | 56.9 | 31.1 | 101.8 | 76.0 | 41.2 |
| 9 | 3+90.5 Roof | 1021.8 | 76.5 | 56.7 | 31.0 | 102.0 | 76.1 | 41.3 |
| 10 | 3+88.5 Roof | 1021.5 | 75.8 | 56.3 | 30.7 | 102.1 | 76.3 | 41.5 |
| 11 | 3+86.5 Roof | 1021.4 | 76.4 | 56.8 | 31.1 | 102.5 | 76.7 | 41.9 |
| 12 | 3+84.5 Roof | 1021.3 | 80.8 | 59.5 | 32.8 | 104.3 | 77.9 | 42.5 |
| 13 | 4+03.5 Corner of Roof | 1031.3 | 98.0 | 70.2 | 35.2 | 104.6 | 76.0 | 37.4 |
| 14 | 4+02.5 Corner of Roof | 1028.2 | 96.1 | 69.8 | 36.6 | 105.9 | 77.5 | 39.7 |
| 15 | 4+01.5 Corner of Roof | 1026.9 | 85.7 | 62.6 | 33.1 | 102.4 | 75.2 | 39.1 |
| 16 | 4+00.5 Corner | 1025.3 | 84.7 | 62.3 | 33.4 | 103.0 | 76.0 | 40.1 |
| 17 | 3+98.5 Corner of Roof | 1024.2 | 84.6 | 61.1 | 33.6 | 103.4 | 76.8 | 40.9 |
| 18 | 3+96.5 Corner of Roof | 1023.1 | 81.7 | 59.9 | 32.9 | 103.0 | 76.7 | 41.1 |
| 19 | 3+94.5 Corner of Roof | 1022.6 | 78.8 | 58.0 | 31.9 | 102.1 | 76.2 | 41.0 |
| 20 | 3+92.5 Corner of Roof | 1022.1 | 77.7 | 56.9 | 31.7 | 102.0 | 76.1 | 41.2 |
| 21 | 3+90.5 Corner of Roof | 1021.8 | 75.8 | 56.5 | 31.0 | 101.7 | 76.2 | 41.3 |
| 22 | 3+88.5 Corner of Roof | 1021.5 | 76.0 | 56.3 | 31.0 | 102.0 | 76.5 | 41.5 |
| 23 | 3+86.5 Corner of Roof | 1021.4 | 76.8 | 56.8 | 31.6 | 102.7 | 77.0 | 42.0 |
| 24 | 3+84.5 Corner of Roof | 1021.3 | 80.9 | 59.7 | 33.2 | 104.4 | 78.4 | 42.7 |
| 25 | 3+74.5 Roof | 1021.3 | 103.2 | 76.7 | 42.2 | 115.7 | 87.0 | 47.5 |
| 26 | 3+49.5 Roof | 1021.3 | * | * | * | * | * | * |
| 27 | 3+29.5 Roof | 1021.3 | * | * | * | * | * | * |
| 28 | 4+29.3 Pier | 1011.3 | 122.2 | 93.7 | 56.0 | 126.5 | 97.6 | 58.0 |
| 29 | 4+27.3 Pier | 1011.3 | 122.9 | 94.2 | 56.4 | 126.3 | 97.8 | 58.0 |
| 30 | 4+23.3 Pier | 1011.3 | 124.0 | 95.1 | 56.8 | 126.7 | 98.2 | 58.2 |
| 31 | 4+15.3 Pier | 1011.3 | 123.2 | 94.3 | 56.5 | 126.5 | 97.9 | 58.1 |
| 32 | 4+09.3 Pier | 1011.3 | 120.2 | 92.2 | 55.2 | 125.2 | 97.0 | 57.5 |
| 33 | 3+98.5 Side | 1011.3 | 108.2 | 83.1 | 50.0 | 120.6 | 93.1 | 55.4 |
| 34 | 3+88.5 Side | 1011.3 | 95.2 | 73.5 | 44.9 | 115.2 | 89.2 | 52.9 |
| 35 | 3+74.5 Side | 1011.3 | 80.9 | 63.2 | 39.0 | 108.5 | 83.6 | 49.4 |
| 36 | 3+49.5 Side | 1011.3 | 10.2 | 9.7 | 9.7 | * | * | * |
| 37 | 3+29.5 Side | 1011.3 | 18.7 | 15.7 | 14.7 | * | * | * |
| 38 | 3+98.5 Invert | 1001.3 | 119.4 | 94.0 | 60.8 | 131.0 | 103.4 | 65.6 |
| 39 | 3+88.5 Invert | 1001.3 | 106.7 | 84.5 | 55.2 | 125.3 | 99.2 | 63.0 |
| 40 | 3+58.5 Invert | 1001.3 | 43.7 | 37.7 | 28.9 | 29.7 | 24.9 | 10.1 |
| 41 | 3+29.5 Invert | 1001.3 | 29.7 | 27.7 | 24.2 | 6.7 | 6.7 | 7.0 |
| | | | | | Intake Transition | | | |
| 42 | 3+17.0 Invert | 1001.3 | 40.7 | 35.7 | 29.2 | 9.4 | 9.0 | 8.7 |
| 43 | 3+17.0 Left Fillet | 1001.8 | 41.7 | 26.7 | 29.5 | 10.0 | 9.7 | 9.0 |
| 44 | 3+17.0 Left Side | 1011.3 | 28.7 | 24.2 | 18.7 | * | * | * |
| 45 | 3+17.0 Left Fillet | 1020.5 | ** | ** | ** | * | * | * |
| 46 | 3+17.0 Roof | 1021.3 | ** | ** | ** | * | * | * |
| 47 | 2+97.4 Invert | 1001.3 | 45.7 | 39.7 | 31.0 | 8.9 | 8.7 | 8.7 |
| 48 | 2+97.4 Left Fillet | 1002.7 | 45.3 | 39.1 | 29.8 | 8.6 | 8.3 | 8.0 |
| 49 | 2+97.4 Left Side | 1011.3 | 36.7 | 30.5 | 21.4 | * | * | * |
| 50 | 2+97.4 Left Fillet | 1019.2 | ** | ** | ** | * | * | * |
| 51 | 2+97.4 Roof | 1021.3 | ** | ** | ** | * | * | * |
| 52 | 2+77.1 Invert | 1001.6 | 40.9 | 35.4 | 27.9 | 1.4 | 2.4 | 5.6 |
| 53 | 2+77.1 Left Fillet | 1003.0 | 41.2 | 35.3 | 27.3 | 3.1 | 4.0 | 5.8 |
| 54 | 2+77.1 Left Side | 1011.2 | 35.1 | 29.1 | 20.3 | * | * | * |
| 55 | 2+77.1 Left Fillet | 1018.7 | ** | ** | ** | * | * | * |
| 56 | 2+77.1 Roof | 1021.2 | ** | ** | ** | * | * | * |
| 57 | 2+98.7 Pier | 1016.3 | 30.7 | 24.6 | 15.5 | * | * | * |
| 58 | 2+90.5 Pier | 1011.3 | 33.2 | 26.9 | 19.3 | * | * | * |
| 59 | 2+82.2 Pier | 1006.2 | 34.8 | 39.8 | 23.0 | -0.7 | 0.3 | 0.5 |
| 60 | 2+90.5 Left Side | 1011.3 | 37.7 | 31.1 | 21.1 | * | * | * |
| | | | | | Horseshoe Conduit | | | |
| 61 | 2+50.0 Invert | 1001.2 | 45.0 | 38.8 | 30.0 | 9.8 | 9.3 | 9.8 |
| 62 | 2+00.0 Invert | 1001.1 | 44.4 | 37.9 | 29.4 | 9.2 | 9.4 | 9.4 |
| 63 | 1+00.0 Invert | 1000.9 | 40.6 | 34.9 | 27.6 | 8.4 | 9.1 | 9.3 |
| 64 | 0+00.0 Invert | 1000.8 | 38.4 | 33.2 | 26.7 | 10.6 | 10.5 | 10.4 |
| 65 | 1+00.0 Invert | 1000.6 | 33.8 | 30.1 | 25.1 | 9.2 | 9.9 | 7.4 |
| 66 | 2+00.0 Invert | 1000.4 | 31.9 | 28.8 | 24.1 | 11.6 | 11.6 | 11.4 |
| 67 | 3+00.0 Invert | 1000.2 | 28.0 | 26.3 | 23.3 | 10.8 | 10.8 | 11.0 |

(Continued)

**See Notes at end of table.**

Table 2 (Continued)

| Piez No. | Piez Station and Location | Piez Zero | Both Gate Passages 3/4 Open: Dischg, 19,500 Pool El, 1140.0 | Dischg, 17,000 Pool El, 1110.0 | Dischg, 12,800 Pool El, 1071.0 | Both Gate Passages 1/2 Open: Dischg, 12,375 Pool El, 1140.0 | Dischg, 10,850 Pool El, 1110.0 | Dischg, 8,400 Pool El, 1071.0 |
|---|---|---|---|---|---|---|---|---|
| | | | | | Downstream Transition | | | |
| 68 | 3+23.0 Invert | 1000.2 | 26.1 | 24.6 | 21.8 | 10.7 | 10.7 | 11.0 |
| 69 | 3+23.0 Left Fillet | 1001.8 | 25.9 | 24.0 | 20.9 | 10.7 | 10.6 | 10.4 |
| 70 | 3+23.0 Left Side | 1010.2 | 17.1 | 15.4 | 12.3 | 1.8 | 2.8 | 2.5 |
| 71 | 3+23.0 Roof | 1020.2 | * | * | * | * | * | * |
| 72 | 3+23.0 Right Side | 1010.2 | 15.6 | 14.2 | 11.3 | 1.4 | * | * |
| 73 | 3+23.0 Right Fillet | 1001.8 | 22.9 | 21.7 | 19.2 | 7.5 | 7.6 | 8.5 |
| 74 | 3+43.0 Invert | 1000.2 | 26.3 | 24.8 | 21.8 | 12.5 | 12.1 | 12.0 |
| 75 | 3+43.0 Left Fillet | 1001.1 | 27.2 | 25.2 | 21.4 | 14.0 | 13.1 | 12.3 |
| 76 | 3+43.0 Left Side | 1010.2 | 16.3 | 14.8 | 11.5 | 2.8 | 2.7 | 2.4 |
| 77 | 3+43.0 Roof | 1020.2 | * | * | * | * | * | * |
| 78 | 3+43.0 Right Side | 1010.2 | 16.7 | 14.9 | 11.8 | 0.8 | * | * |
| 79 | 3+43.0 Right Fillet | 1001.1 | 24.5 | 23.1 | 20.4 | 10.2 | 10.2 | 10.4 |
| 80 | 3+63.0 Invert | 1000.1 | 24.0 | 22.7 | 20.7 | 11.7 | 11.9 | 12.2 |
| 81 | 3+63.0 Left Fillet | 1000.5 | 24.5 | 23.4 | 20.5 | 12.6 | 12.3 | 12.2 |
| 82 | 3+63.0 Left Side | 1010.1 | 15.1 | 13.9 | 10.9 | 3.3 | 2.3 | 2.2 |
| 83 | 3+63.0 Roof | 1020.1 | * | * | * | * | * | * |
| 84 | 3+63.0 Right Side | 1010.1 | 12.4 | 11.7 | 9.7 | 0.2 | 1.2 | 2.2 |
| 85 | 3+63.0 Right Fillet | 1000.5 | 21.2 | 20.8 | 19.2 | 8.9 | 10.1 | 11.2 |
| | | | | | Rectangular Conduit | | | |
| 86 | 4+00 Invert | 1000.1 | 19.2 | 19.4 | 18.7 | 10.6 | 11.4 | 12.2 |
| 87 | 4+90 Invert | 999.9 | 13.1 | 14.4 | 20.1 | 10.5 | 10.7 | 12.1 |

Notes: Pressures are recorded in prototype feet of water.
Discharges are recorded in cubic feet per second.
Pool elevations are recorded in feet above mean sea level.
All pressure measurements confined to right half of outlet structure.
*Piezometer is above water surface.
**Piezometer will not prime due to air.

## Table 3

### PRESSURES THROUGHOUT OUTLET STRUCTURES, ORIGINAL DESIGN

Left Gate Passage Open - Right Gate Passage Closed

| Piez No. | Piez Station and Location | Piez Zero | Left Gate Passage Open Full: Dischg, 15,300 Pool El, 1140.0 | Left Gate Passage Open Full: Dischg, 13,200 Pool El, 1110.0 | Left Gate Passage Open Full: Dischg, 10,000 Pool El, 1071.0 | Left Gate Passage 3/4 Open: Dischg, 9,750 Pool El, 1140.0 | Left Gate Passage 3/4 Open: Dischg, 8,650 Pool El, 1110.0 | Left Gate Passage 3/4 Open: Dischg, 6,600 Pool El, 1071.0 |
|---|---|---|---|---|---|---|---|---|
| 1 | 4+03.5 Roof | 1031.3 | 83.2 | 58.7 | 29.3 | 98.4 | 70.2 | 35.5 |
| 2 | 4+02.5 Roof | 1028.2 | 73.5 | 52.2 | 26.8 | 95.6 | 69.1 | 36.3 |
| 3 | 4+01.5 Roof | 1026.9 | 48.7 | 33.6 | 16.3 | 86.4 | 62.5 | 32.6 |
| 4 | 4+00.5 Roof | 1025.3 | 42.5 | 29.9 | 14.5 | 85.1 | 61.5 | 32.5 |
| 5 | 3+98.5 Roof | 1024.2 | 38.5 | 27.0 | 13.0 | 84.2 | 61.2 | 32.6 |
| 6 | 3+96.5 Roof | 1023.1 | 29.3 | 20.5 | 9.9 | 81.2 | 59.2 | 32.1 |
| 7 | 3+94.5 Roof | 1022.6 | 20.2 | 13.9 | 6.3 | 77.9 | 56.4 | 30.9 |
| 8 | 3+92.5 Roof | 1022.1 | 14.9 | 9.9 | 4.3 | 76.4 | 56.4 | 30.4 |
| 9 | 3+90.5 Roof | 1021.8 | 11.4 | 7.7 | 3.0 | 75.6 | 55.7 | 30.2 |
| 10 | 3+88.5 Roof | 1021.5 | 7.6 | 4.7 | 1.5 | 74.6 | 55.0 | 30.1 |
| 11 | 3+86.5 Roof | 1021.4 | 7.8 | 4.9 | 1.6 | 75.6 | 55.7 | 30.5 |
| 12 | 3+84.5 Roof | 1021.3 | 16.4 | 11.1 | 5.4 | 79.8 | 55.8 | 32.1 |
| 13 | 4+03.5 Corner of Roof | 1031.3 | 83.9 | 59.9 | 29.3 | 99.0 | 71.2 | 35.4 |
| 14 | 4+02.5 Corner of Roof | 1028.2 | 76.3 | 54.8 | 27.3 | 97.4 | 70.7 | 36.6 |
| 15 | 4+01.5 Corner of Roof | 1026.9 | 48.1 | 33.8 | 16.1 | 86.4 | 63.0 | 32.8 |
| 16 | 4+00.5 Corner of Roof | 1025.3 | 42.2 | 30.0 | 14.4 | 85.1 | 62.3 | 32.9 |
| 17 | 3+98.5 Corner of Roof | 1024.2 | 38.6 | 27.8 | 13.8 | 84.4 | 61.9 | 33.1 |
| 18 | 3+96.5 Corner of Roof | 1023.1 | 27.5 | 19.7 | 9.4 | 81.0 | 59.3 | 32.2 |
| 19 | 3+94.5 Corner of Roof | 1022.6 | 18.7 | 13.3 | 6.1 | 77.6 | 56.9 | 31.0 |
| 20 | 3+92.5 Corner of Roof | 1022.1 | 14.1 | 9.4 | 4.2 | 76.2 | 56.4 | 30.7 |
| 21 | 3+90.5 Corner of Roof | 1021.8 | 9.4 | 6.2 | 2.2 | 74.7 | 55.2 | 30.1 |
| 22 | 3+88.5 Corner of Roof | 1021.5 | 7.0 | 4.4 | 1.5 | 74.5 | 54.9 | 30.1 |
| 23 | 3+86.5 Corner of Roof | 1021.4 | 7.6 | 4.6 | 1.7 | 75.3 | 55.8 | 30.6 |
| 24 | 3+84.5 Corner of Roof | 1021.3 | 16.0 | 11.1 | 5.2 | 79.5 | 58.4 | 32.3 |
| 25 | 3+74.5 Roof | 1021.3 | 18.5 | 13.6 | 7.2 | 102.9 | 76.3 | 42.7 |
| 26 | 3+49.5 Roof | 1021.3 | 18.9 | 13.9 | 6.7 | * | * | * |
| 27 | 3+29.5 Roof | 1021.3 | 19.1 | 13.9 | 6.7 | * | * | * |
| 28 | 4+29.3 Pier | 1011.3 | 114.9 | 89.3 | 33.9 | 124.2 | 95.0 | 57.7 |
| 29 | 4+27.3 Pier | 1011.3 | 116.2 | 90.4 | 54.5 | 124.8 | 95.5 | 57.9 |
| 30 | 4+23.3 Pier | 1011.3 | 114.7 | 89.3 | 53.9 | 124.2 | 95.0 | 57.7 |
| 31 | 4+15.3 Pier | 1011.3 | 111.2 | 86.7 | 52.5 | 122.9 | 93.8 | 57.0 |
| 32 | 4+09.3 Pier | 1011.3 | 103.4 | 80.8 | 49.3 | 119.5 | 91.3 | 55.6 |
| 33 | 3+98.5 Side | 1011.3 | 75.0 | 59.2 | 36.9 | 107.3 | 82.2 | 50.5 |
| 34 | 3+88.5 Side | 1011.3 | 43.5 | 35.1 | 23.3 | 93.6 | 72.0 | 44.5 |
| 35 | 3+74.5 Side | 1011.3 | 34.1 | 27.7 | 18.7 | 78.8 | 61.0 | 37.8 |
| 36 | 3+49.5 Side | 1011.3 | 28.7 | 23.9 | 16.7 | 3.2 | 3.2 | 1.7 |
| 37 | 3+29.5 Side | 1011.3 | 24.2 | 19.7 | 14.3 | -6.0 | -4.5 | -4.3 |
| 38 | 3+98.5 Invert | 1001.3 | 89.0 | 71.7 | 48.2 | 119.7 | 93.1 | 60.7 |
| 39 | 3+88.5 Invert | 1001.3 | 60.5 | 50.1 | 36.0 | 105.8 | 83.5 | 55.1 |
| 40 | 3+58.5 Invert | 1001.3 | 39.7 | 34.9 | 27.4 | 40.5 | 33.9 | 25.5 |
| 41 | 3+29.5 Invert | 1001.3 | 37.3 | 32.2 | 25.6 | 10.9 | 11.0 | 11.5 |
| 42 | 3+17.7 Invert | 1001.3 | 38.5 | 33.0 | 26.1 | 14.8 | 14.4 | 13.4 |
| 43 | 3+17.7 Left Fillet | 1001.8 | 39.8 | 33.9 | 26.6 | 16.2 | 15.3 | 13.8 |
| 44 | 3+17.7 Left Side | 1011.3 | 30.5 | 24.5 | 17.1 | 3.0 | 2.7 | 2.5 |
| 45 | 3+17.7 Left Fillet | 1020.5 | 23.4 | 16.7 | 8.7 | * | * | * |
| 46 | 3+17.7 Roof | 1021.3 | 18.4 | 12.8 | 6.2 | * | * | * |
| 47 | 2+97.4 Invert | 1001.3 | 21.9 | 20.2 | 18.5 | 12.7 | 12.4 | 12.2 |
| 48 | 2+97.4 Left Fillet | 1002.7 | 22.7 | 20.5 | 18.3 | 13.0 | 12.8 | 11.9 |
| 49 | 2+97.4 Left Side | 1011.3 | 14.5 | 12.3 | 9.7 | 4.9 | 4.3 | 3.8 |
| 50 | 2+97.4 Left Fillet | 1019.3 | 4.5 | 3.0 | 1.5 | * | * | * |
| 51 | 2+97.4 Roof | 1021.3 | -0.7 | -0.9 | -0.8 | * | * | * |
| 52 | 2+77.1 Invert | 1001.6 | -1.8 | 1.4 | 5.9 | -0.7 | 1.4 | 3.7 |
| 53 | 2+77.1 Left Fillet | 1003.0 | 0.7 | 2.5 | 7.1 | 1.4 | 3.0 | 5.1 |
| 54 | 2+77.1 Left Side | 1011.2 | -1.7 | -0.3 | 2.9 | 1.6 | 1.8 | 2.2 |
| 55 | 2+77.1 Left Fillet | 1018.7 | -9.2 | -6.8 | -2.6 | * | * | * |
| 56 | 2+77.1 Roof | 1021.2 | * | * | * | * | * | * |
| 57 | 2+98.7 Pier | 1016.3 | -5.3 | -3.4 | -0.8 | * | * | * |
| 58 | 2+90.5 Pier | 1011.3 | -4.1 | -2.1 | 0.5 | -1.3 | -0.5 | -0.1 |
| 59 | 2+82.2 Pier | 1006.2 | -3.9 | -1.7 | 1.0 | -3.5 | -1.6 | 0.3 |
| 60 | 2+90.5 Left Side | 1011.3 | 7.4 | 6.7 | 6.4 | 4.5 | 4.2 | 3.5 |
| | | | | | Horseshoe Conduit | | | |
| 61 | 2+50.0 Invert | 1001.2 | 7.5 | 16.0 | 18.6 | 9.3 | 10.3 | 10.4 |
| 62 | 2+00.0 Invert | 1001.1 | 13.1 | 12.1 | 10.0 | 8.1 | 7.5 | 6.2 |
| 63 | 1+00.0 Invert | 1000.9 | 7.6 | 11.7 | 10.4 | 6.9 | 8.1 | 7.1 |
| 64 | 0+00.0 Invert | 1000.8 | 11.5 | 12.7 | 12.2 | 8.4 | 9.0 | 8.4 |
| 65 | 1+00.0 Invert | 1000.6 | 10.7 | 11.7 | 11.7 | 7.2 | 8.6 | 8.4 |
| 66 | 2+00.0 Invert | 1000.4 | 13.6 | 13.8 | 13.1 | 9.6 | 10.0 | 9.1 |
| 67 | 3+00.0 Invert | 1000.2 | 12.5 | 12.5 | 12.6 | 8.6 | 8.8 | 9.3 |

(Continued)

See Notes at end of table.

Table 3 (Continued)

| Piez No. | Piez Station and Location | Piez Zero | Left Gate Passage Open Full | | | Left Gate Passage 3/4 Open | | |
|---|---|---|---|---|---|---|---|---|
| | | | Dischg, 15,300 Pool El, 1140.0 | Dischg, 13,200 Pool El, 1110.0 | Dischg, 10,000 Pool El, 1071.0 | Dischg, 9,750 Pool El, 1140.0 | Dischg, 8,650 Pool El, 1110.0 | Dischg, 6,600 Pool El, 1071.0 |
| | | | | | Downstream Transition | | | |
| 68 | 3+23.0 Invert | 1000.2 | 12.5 | 12.4 | 12.8 | 8.7 | 8.6 | 9.0 |
| 69 | 3+23.0 Left Fillet | 1001.8 | 12.4 | 12.6 | 12.3 | 7.9 | 9.0 | 8.8 |
| 70 | 3+23.0 Left Side | 1010.2 | 3.1 | 4.5 | 4.2 | * | 2.1 | 2.0 |
| 71 | 3+23.0 Roof | 1020.2 | * | * | * | * | * | * |
| 72 | 3+23.0 Right Side | 1010.2 | 3.7 | 1.8 | 1.8 | 1.5 | * | * |
| 73 | 3+23.0 Right Fillet | 1001.8 | 9.6 | 9.3 | 10.1 | 6.3 | 4.7 | 5.7 |
| 74 | 3+43.0 Invert | 1000.2 | 15.0 | 14.4 | 14.1 | 11.0 | 9.8 | 9.8 |
| 75 | 3+43.0 Left Fillet | 1001.1 | 16.7 | 15.3 | 14.2 | 11.5 | 10.8 | 10.1 |
| 76 | 3+43.0 Left Side | 1010.2 | 5.1 | 5.1 | 3.9 | * | 1.8 | 1.6 |
| 77 | 3+43.0 Roof | 1020.2 | * | * | * | * | * | * |
| 78 | 3+43.0 Right Side | 1010.2 | 5.0 | 3.6 | 4.2 | * | * | * |
| 79 | 3+43.0 Right Fillet | 1001.1 | 13.0 | 12.8 | 13.1 | 8.4 | 6.7 | 7.3 |
| 80 | 3+63.0 Invert | 1000.1 | 13.9 | 14.0 | 14.0 | 10.3 | 10.2 | 10.1 |
| 81 | 3+63.0 Left Fillet | 1000.5 | 15.0 | 14.5 | 14.2 | 10.8 | 10.6 | 10.0 |
| 82 | 3+63.0 Left Side | 1010.1 | 5.9 | 4.8 | 3.9 | 1.7 | 1.3 | * |
| 83 | 3+63.0 Roof | 1020.1 | * | * | * | * | * | * |
| 84 | 3+63.0 Right Side | 1010.1 | 2.7 | 4.1 | 4.6 | * | * | * |
| 85 | 3+63.0 Right Fillet | 1000.5 | 11.8 | 12.9 | 13.5 | 7.0 | 8.1 | 9.2 |
| | | | | | Rectangular Conduit | | | |
| 86 | 4+00.0 Invert | 1000.1 | 12.2 | 13.9 | 14.7 | 6.8 | 8.9 | 9.6 |
| 87 | 4+90.0 Invert | 999.9 | 11.3 | 12.5 | 13.6 | 8.8 | 8.9 | 9.4 |

| Piez No. | Piez Station and Location | Piez Zero | Left Gate Passage 1/2 Open | | | Left Gate Passage 1/4 Open | | |
|---|---|---|---|---|---|---|---|---|
| | | | Dischg, 6,200 Pool El, 1140.0 | Dischg, 5,400 Pool El, 1110.0 | Dischg, 4,075 Pool El, 1071.0 | Dischg, 3,140 Pool El, 1140.0 | Dischg, 2,780 Pool El, 1110.0 | Dischg, 2,250 Pool El, 1071.0 |
| 1 | 4+03.5 Roof | 1031.3 | 105.3 | 76.0 | 37.9 | 108.3 | 77.9 | 39.0 |
| 2 | 4+02.5 Roof | 1028.2 | 106.0 | 77.2 | 40.0 | 110.7 | 80.3 | 41.8 |
| 3 | 4+01.5 Roof | 1026.9 | 103.3 | 75.5 | 39.3 | 111.2 | 81.0 | 42.5 |
| 4 | 4+00.5 Roof | 1025.3 | 103.6 | 76.1 | 40.0 | 112.4 | 82.4 | 43.9 |
| 5 | 3+98.5 Roof | 1024.2 | 103.9 | 76.5 | 40.8 | 113.3 | 83.3 | 44.9 |
| 6 | 3+96.5 Roof | 1023.1 | 103.6 | 76.5 | 41.2 | 114.0 | 84.2 | 45.9 |
| 7 | 3+94.5 Roof | 1022.6 | 102.6 | 76.0 | 41.1 | 114.1 | 84.4 | 46.3 |
| 8 | 3+92.5 Roof | 1022.1 | 102.4 | 76.0 | 41.2 | 114.4 | 84.8 | 46.7 |
| 9 | 3+90.5 Roof | 1021.8 | 102.5 | 76.1 | 41.4 | 114.7 | 85.0 | 47.0 |
| 10 | 3+88.5 Roof | 1021.5 | 102.6 | 76.2 | 41.6 | 114.9 | 85.3 | 47.3 |
| 11 | 3+86.5 Roof | 1021.4 | 103.3 | 76.7 | 42.0 | 115.2 | 85.6 | 47.5 |
| 12 | 3+84.5 Roof | 1021.3 | 104.4 | 77.6 | 42.5 | 115.4 | 85.8 | 47.6 |
| 13 | 4+03.5 Corner of Roof | 1031.3 | 105.4 | 76.2 | 37.7 | 108.2 | 78.0 | 39.1 |
| 14 | 4+02.5 Corner of Roof | 1028.2 | 106.8 | 77.8 | 40.3 | 110.8 | 80.7 | 41.9 |
| 15 | 4+01.5 Corner of Roof | 1026.9 | 103.3 | 75.6 | 39.2 | 110.9 | 81.1 | 42.6 |
| 16 | 4+00.5 Corner of Roof | 1025.3 | 103.5 | 76.2 | 40.2 | 112.2 | 82.5 | 44.1 |
| 17 | 3+98.5 Corner of Roof | 1024.2 | 104.0 | 76.7 | 41.0 | 113.1 | 83.4 | 45.1 |
| 18 | 3+96.5 Corner of Roof | 1023.1 | 103.6 | 76.6 | 41.4 | 113.8 | 84.2 | 46.0 |
| 19 | 3+94.5 Corner of Roof | 1022.6 | 102.4 | 76.0 | 41.1 | 113.9 | 84.4 | 46.4 |
| 20 | 3+92.5 Corner of Roof | 1022.1 | 102.5 | 75.9 | 41.3 | 114.2 | 84.8 | 46.8 |
| 21 | 3+90.5 Corner of Roof | 1021.8 | 102.3 | 75.8 | 41.4 | 114.4 | 85.0 | 47.0 |
| 22 | 3+88.5 Corner of Roof | 1021.5 | 102.6 | 76.1 | 41.6 | 114.7 | 85.3 | 47.3 |
| 23 | 3+86.5 Corner of Roof | 1021.4 | 103.0 | 76.5 | 42.0 | 115.0 | 85.5 | 47.6 |
| 24 | 3+84.5 Corner of Roof | 1021.3 | 105.0 | 77.9 | 42.9 | 115.5 | 86.0 | 47.8 |
| 25 | 3+74.5 Roof | 1021.3 | 115.8 | 86.4 | 30.3 | 118.4 | 88.1 | 49.1 |
| 26 | 3+49.5 Roof | 1021.3 | * | * | * | * | * | * |
| 27 | 3+29.5 Roof | 1021.3 | * | * | * | * | * | * |
| 28 | 4+29.3 Pier | 1011.3 | 127.4 | 97.6 | 58.8 | 128.7 | 98.3 | 59.2 |
| 29 | 4+27.3 Pier | 1011.3 | 127.9 | 97.8 | 58.9 | 128.7 | 98.4 | 59.2 |
| 30 | 4+23.3 Pier | 1011.3 | 127.6 | 97.6 | 58.8 | 128.7 | 98.3 | 59.2 |
| 31 | 4+15.3 Pier | 1011.3 | 127.0 | 97.3 | 58.6 | 128.5 | 98.2 | 59.1 |
| 32 | 4+09.3 Pier | 1011.3 | 125.9 | 96.3 | 58.1 | 128.2 | 98.0 | 59.0 |
| 33 | 3+98.5 Side | 1011.3 | 121.0 | 92.7 | 55.9 | 126.9 | 97.1 | 58.5 |
| 34 | 3+88.5 Side | 1011.3 | 115.8 | 88.5 | 53.4 | 125.7 | 96.0 | 57.8 |
| 35 | 3+74.5 Side | 1011.3 | 109.0 | 83.4 | 50.2 | 125.2 | 95.6 | 57.7 |
| 36 | 3+49.5 Side | 1011.3 | * | * | * | * | * | * |
| 37 | 3+29.5 Side | 1011.3 | * | * | * | * | * | * |
| 38 | 3+98.5 Invert | 1001.3 | 131.3 | 102.8 | 65.9 | 137.1 | 107.1 | 68.6 |
| 39 | 3+88.5 Invert | 1001.3 | 125.7 | 98.4 | 63.3 | 135.5 | 106.0 | 67.8 |
| 40 | 3+58.5 Invert | 1001.3 | 31.2 | 26.3 | 19.8 | 11.2 | 9.9 | 8.0 |
| 41 | 3+29.5 Invert | 1001.3 | 6.3 | 6.6 | 7.1 | 3.2 | 3.3 | 3.7 |

(Continued)

See Notes at end of table.

Table 3 (Continued)

| Piez No. | Piez Station and Location | Piez Zero | Left Gate Passage 1/2 Open: Dischg, 6,200 Pool El, 1140.0 | Dischg, 5,400 Pool El, 1110.0 | Dischg, 4,075 Pool El, 1071.0 | Left Gate Passage 1/4 Open: Dischg, 3,140 Pool El, 1140.0 | Dischg, 2,780 Pool El, 1110.0 | Dischg, 2,250 Pool El, 1071.0 |
|---|---|---|---|---|---|---|---|---|
| 42 | 3+17.7 Invert | 1001.3 | 9.0 | 8.9 | 8.8 | 4.5 | 4.5 | 4.7 |
| 43 | 3+17.7 Left Fillet | 1001.8 | 9.9 | 9.6 | 9.0 | 5.4 | 5.2 | 5.0 |
| 44 | 3+17.7 Left Side | 1011.3 | * | * | * | * | * | * |
| 45 | 3+17.7 Left Fillet | 1020.5 | * | * | * | * | * | * |
| 46 | 3+17.7 Roof | 1021.3 | * | * | * | * | * | * |
| 47 | 2+97.4 Invert | 1001.3 | 8.7 | 8.7 | 8.4 | 4.3 | 4.6 | 4.8 |
| 48 | 2+97.4 Left Fillet | 1002.7 | 8.8 | 8.6 | 7.9 | 4.6 | 4.5 | 4.3 |
| 49 | 2+97.4 Left Side | 1011.3 | * | * | * | * | * | * |
| 50 | 2+97.4 Left Fillet | 1019.2 | * | * | * | * | * | * |
| 51 | 2+97.4 Roof | 1021.3 | * | * | * | * | * | * |
| 52 | 2+77.1 Invert | 1001.6 | 0.4 | 1.9 | 3.4 | 1.4 | 1.9 | 2.7 |
| 53 | 2+77.1 Left Fillet | 1003.0 | 2.1 | 2.9 | 4.2 | 2.0 | 2.4 | 2.9 |
| 54 | 2+77.1 Left Side | 1011.2 | * | * | * | * | * | * |
| 55 | 2+77.1 Left Fillet | 1018.7 | * | * | * | * | * | * |
| 56 | 2+77.1 Roof | 1021.2 | * | * | * | * | * | * |
| 57 | 2+98.7 Pier | 1016.3 | * | * | * | * | * | * |
| 58 | 2+90.5 Pier | 1011.3 | * | * | * | * | * | * |
| 59 | 2+82.2 Pier | 1006.2 | -1.5 | -0.2 | * | * | * | * |
| 60 | 2+90.5 Left Side | 1011.3 | * | * | * | * | * | * |
| | | | | | Horseshoe Conduit | | | |
| 61 | 2+50 Invert | 1001.2 | 6.3 | 6.4 | 6.8 | 4.0 | 4.4 | 4.4 |
| 62 | 2+00 Invert | 1001.1 | 5.2 | 5.2 | 4.4 | 3.0 | 2.8 | 2.6 |
| 63 | 1+00 Invert | 1000.9 | 4.7 | 5.3 | 4.8 | 3.4 | 3.3 | 3.1 |
| 64 | 0+00 Invert | 1000.8 | 6.4 | 6.6 | 6.4 | 4.6 | 4.2 | 4.4 |
| 65 | 1+00 Invert | 1000.6 | 5.1 | 6.2 | 6.0 | 4.0 | 3.7 | 4.0 |
| 66 | 2+00 Invert | 1000.4 | 6.9 | 7.4 | 6.9 | 5.3 | 5.3 | 5.0 |
| 67 | 3+00 Invert | 1000.2 | 6.6 | 6.5 | 6.6 | 5.0 | 5.0 | 5.0 |
| | | | | | Downstream Transition | | | |
| 68 | 3+23 Invert | 1000.2 | 6.9 | 6.6 | 6.7 | 4.8 | 4.8 | 4.9 |
| 69 | 3+23 Left Fillet | 1001.8 | 6.2 | 6.5 | 6.5 | 4.8 | 3.1 | 3.4 |
| 70 | 3+23 Left Side | 1010.2 | * | * | * | * | * | * |
| 71 | 3+23 Roof | 1020.2 | * | * | * | * | * | * |
| 72 | 3+23 Right Side | 1010.2 | * | * | * | * | * | * |
| 73 | 3+23 Right Fillet | 1001.8 | 4.5 | 3.0 | 3.5 | 2.0 | 3.6 | 3.5 |
| 74 | 3+43 Invert | 1000.2 | 7.7 | 7.4 | 7.2 | 4.8 | 4.6 | 4.6 |
| 75 | 3+43 Left Fillet | 1001.1 | 8.9 | 7.9 | 7.2 | 5.7 | 3.6 | 3.6 |
| 76 | 3+43 Left Side | 1010.2 | * | * | * | * | * | * |
| 77 | 3+43 Roof | 1020.2 | * | * | * | * | * | * |
| 78 | 3+43 Right Side | 1010.2 | * | * | * | * | * | * |
| 79 | 3+43 Right Fillet | 1001.1 | 4.8 | 4.7 | 5.1 | 1.8 | 3.7 | 3.8 |
| 80 | 3+63 Invert | 1000.1 | 6.8 | 6.6 | 6.5 | 4.1 | 4.1 | 4.1 |
| 81 | 3+63 Left Fillet | 1000.5 | 7.7 | 6.5 | 5.8 | 4.8 | 4.2 | 4.0 |
| 82 | 3+63 Left Side | 1010.1 | * | * | * | * | * | * |
| 83 | 3+63 Roof | 1020.1 | * | * | * | * | * | * |
| 84 | 3+63 Right Side | 1010.1 | * | * | * | * | * | * |
| 85 | 3+63 Right Fillet | 1000.5 | 2.5 | 5.9 | 6.5 | 6.9 | 2.7 | 2.9 |
| 86 | 4+00 Invert | 1000.1 | 6.1 | 6.1 | 6.6 | 8.2 | 3.5 | 3.9 |
| 87 | 4+90 Invert | 999.9 | 7.1 | 7.0 | 7.3 | 4.7 | 4.6 | 4.9 |

Notes: Pressures are recorded in prototype feet of water.
Discharges are recorded in cubic feet per second.
Pool elevations are recorded in feet above mean sea level.
All pressure measurements confined to right half of outlet structure.
*Piezometer is above water surface.

Table 4

PRESSURES THROUGHOUT OUTLET STRUCTURES, ORIGINAL DESIGN

Left Gate Passage Open Full, Right Gate Passage Partially Open

| Piez No. | Piez Station and Location | Piez Zero | Right Gate Passage 3/4 Open: Dischg, 21,750 Pool El, 1140.0 | Right Gate Passage 3/4 Open: Dischg, 19,100 Pool El, 1110.0 | Right Gate Passage 3/4 Open: Dischg, 14,250 Pool El, 1071.0 | Right Gate Passage 1/2 Open: Dischg, 20,000 Pool El, 1140.0 | Right Gate Passage 1/2 Open: Dischg, 17,400 Pool El, 1110.0 | Right Gate Passage 1/2 Open: Dischg, 13,000 Pool El, 1071.0 |
|---|---|---|---|---|---|---|---|---|
| 1 | 4+03.5 Roof | 1031.3 | 90.0 | 64.9 | 32.9 | 86.4 | 62.4 | 31.4 |
| 2 | 4+02.5 Roof | 1028.2 | 83.4 | 61.1 | 32.3 | 78.0 | 57.0 | 30.6 |
| 3 | 4+01.5 Roof | 1026.9 | 68.5 | 49.0 | 25.9 | 58.4 | 41.9 | 21.8 |
| 4 | 4+00.5 Roof | 1025.3 | 64.9 | 47.1 | 25.1 | 53.7 | 39.5 | 20.6 |
| 5 | 3+98.5 Roof | 1024.2 | 62.6 | 46.0 | 24.8 | 51.2 | 37.8 | 19.9 |
| 6 | 3+96.5 Roof | 1023.1 | 57.4 | 42.4 | 23.2 | 43.1 | 32.5 | 17.5 |
| 7 | 3+94.5 Roof | 1022.6 | 49.1 | 36.4 | 20.4 | 34.0 | 26.2 | 13.6 |
| 8 | 3+92.5 Roof | 1022.1 | 48.1 | 35.4 | 19.9 | 32.4 | 24.6 | 13.4 |
| 9 | 3+90.5 Roof | 1021.8 | 46.2 | 34.2 | 19.3 | 29.4 | 22.8 | 12.5 |
| 10 | 3+88.5 Roof | 1021.5 | 43.7 | 32.3 | 18.7 | 26.7 | 20.0 | 11.6 |
| 11 | 3+86.5 Roof | 1021.4 | 44.1 | 32.4 | 18.8 | 26.9 | 20.8 | 11.7 |
| 12 | 3+84.5 Roof | 1021.3 | 49.5 | 36.7 | 21.0 | 33.9 | 25.5 | 13.7 |
| 13 | 4+03.5 Corner of Roof | 1031.3 | 90.9 | 65.7 | 33.2 | 87.2 | 63.4 | 31.0 |
| 14 | 4+02.5 Corner of Roof | 1028.2 | 86.3 | 62.3 | 33.1 | 81.4 | 58.0 | 30.8 |
| 15 | 4+01.5 Corner of Roof | 1026.9 | 67.6 | 49.1 | 26.3 | 58.6 | 42.9 | 21.9 |
| 16 | 4+00.5 Corner of Roof | 1025.3 | 65.3 | 47.7 | 26.0 | 54.2 | 40.2 | 21.2 |
| 17 | 3+98.5 Corner of Roof | 1024.2 | 63.6 | 46.8 | 25.6 | 51.5 | 39.0 | 21.0 |
| 18 | 3+96.5 Corner of Roof | 1023.1 | 57.4 | 41.7 | 23.6 | 43.1 | 32.9 | 18.1 |
| 19 | 3+94.5 Corner of Roof | 1022.6 | 51.6 | 37.3 | 21.9 | 36.6 | 27.6 | 15.6 |
| 20 | 3+92.5 Corner of Roof | 1022.1 | 48.6 | 35.7 | 20.7 | 32.6 | 24.5 | 14.2 |
| 21 | 3+90.5 Corner of Roof | 1021.8 | 45.0 | 33.0 | 19.5 | 27.8 | 21.4 | 12.4 |
| 22 | 3+88.5 Corner of Roof | 1021.5 | 44.0 | 32.4 | 19.0 | 25.7 | 20.5 | 12.0 |
| 23 | 3+86.5 Corner of Roof | 1021.4 | 44.4 | 32.6 | 19.1 | 26.4 | 20.7 | 12.1 |
| 24 | 3+84.5 Corner of Roof | 1021.3 | 50.5 | 37.2 | 21.3 | 34.5 | 26.2 | 15.3 |
| 25 | 3+74.5 Roof | 1021.3 | 52.2 | 38.5 | 22.4 | 36.0 | 27.2 | 16.2 |
| 26 | 3+49.5 Roof | 1021.3 | 50.0 | 38.7 | 21.7 | 37.2 | 28.2 | 15.7 |
| 27 | 3+29.5 Roof | 1021.3 | 49.9 | 38.7 | 21.7 | 37.2 | 28.2 | 15.7 |
| 28 | 4+29.3 Pier | 1011.3 | 116.5 | 90.4 | 56.2 | 116.7 | 89.7 | 55.0 |
| 29 | 4+27.3 Pier | 1011.3 | 117.5 | 91.3 | 56.3 | 118.3 | 91.2 | 55.7 |
| 30 | 4+23.3 Pier | 1011.3 | 118.7 | 92.2 | 56.7 | 118.4 | 90.9 | 55.5 |
| 31 | 4+15.3 Pier | 1011.3 | 117.4 | 92.2 | 55.7 | 116.1 | 89.4 | 54.4 |
| 32 | 4+09.3 Pier | 1011.3 | 112.5 | 87.4 | 53.9 | 109.7 | 84.7 | 52.2 |
| 33 | 3+98.5 Side | 1011.3 | 92.3 | 72.5 | 45.2 | 85.9 | 67.2 | 42.1 |
| 34 | 3+88.5 Side | 1011.3 | 71.0 | 56.2 | 36.9 | 59.0 | 47.2 | 31.2 |
| 35 | 3+74.5 Side | 1011.3 | 64.5 | 40.9 | 33.4 | 51.0 | 41.2 | 27.2 |
| 36 | 3+49.5 Side | 1011.3 | 60.7 | 48.7 | 31.7 | 47.7 | 38.2 | 25.7 |
| 37 | 3+27.5 Side | 1011.3 | 56.5 | 45.2 | 30.2 | 42.4 | 34.7 | 23.7 |
| 38 | 3+98.5 Invert | 1001.3 | 106.3 | 84.2 | 56.3 | 98.2 | 77.7 | 52.7 |
| 39 | 3+88.5 Invert | 1001.3 | 86.5 | 69.4 | 48.5 | 75.2 | 60.9 | 43.5 |
| 40 | 3+58.5 Invert | 1001.3 | 70.7 | 58.7 | 41.7 | 56.2 | 48.7 | 35.7 |
| 41 | 3+29.5 Invert | 1001.3 | 68.7 | 56.7 | 41.0 | 55.2 | 46.5 | 34.5 |
| 42 | 3+17.7 Invert | 1001.3 | 70.7 | 57.4 | 41.3 | 55.7 | 47.5 | 35.0 |
| 43 | 3+17.7 Left Fillet | 1001.8 | 71.2 | 58.2 | 41.6 | 57.2 | 47.7 | 35.3 |
| 44 | 3+17.7 Left Side | 1011.3 | 61.9 | 48.7 | 31.7 | 47.7 | 38.2 | 25.2 |
| 45 | 3+17.7 Left Fillet | 1020.5 | 54.0 | 40.3 | 23.0 | 40.0 | 30.0 | 17.0 |
| 46 | 3+17.7 Roof | 1021.3 | 50.3 | 37.3 | 21.4 | 35.7 | 26.7 | 15.2 |
| 47 | 2+97.4 Invert | 1001.3 | 60.9 | 49.9 | 36.7 | 45.3 | 39.3 | 30.7 |
| 48 | 2+97.4 Left Fillet | 1002.7 | 60.4 | 49.3 | 35.9 | 45.3 | 38.8 | 30.0 |
| 49 | 2+97.4 Left Side | 1011.3 | 51.7 | 41.0 | 27.1 | 36.2 | 29.7 | 21.2 |
| 50 | 2+97.4 Left Fillet | 1019.2 | 42.8 | 32.1 | 19.0 | 25.1 | 20.3 | 12.3 |
| 51 | 2+97.4 Roof | 1021.3 | 39.0 | 28.4 | 16.2 | 17.2 | 13.2 | 8.0 |
| 52 | 2+77.1 Invert | 1001.6 | 45.2 | 38.4 | 30.2 | 37.1 | 32.9 | 26.6 |
| 53 | 2+77.1 Left Fillet | 1003.0 | 45.7 | 38.2 | 29.6 | 37.1 | 32.5 | 26.0 |
| 54 | 2+77.1 Left Side | 1011.2 | 39.6 | 31.6 | 21.8 | 31.4 | 26.1 | 18.3 |
| 55 | 2+77.1 Left Fillet | 1018.7 | 29.5 | 23.1 | 13.8 | 22.8 | 17.5 | 10.3 |
| 56 | 2+77.1 Roof | 1021.2 | 30.3 | 22.8 | 12.3 | 26.6 | 19.2 | 10.4 |
| 57 | 2+98.7 Pier | 1016.3 | 36.9 | 29.0 | 18.7 | 14.2 | 12.7 | 9.7 |
| 58 | 2+90.5 Pier | 1011.3 | 39.5 | 31.9 | 22.5 | 21.7 | 20.2 | 15.7 |
| 59 | 2+82.2 Pier | 1006.2 | 39.3 | 33.3 | 25.3 | 28.3 | 25.3 | 20.8 |
| 60 | 2+90.5 Left Side | 1011.3 | 46.4 | 37.2 | 25.0 | 33.0 | 26.7 | 19.4 |
| | Horseshoe Conduit | | | | | | | |
| 61 | 2+50.0 Invert | 1001.2 | 47.6 | 40.1 | 31.1 | 45.0 | 38.1 | 29.3 |
| 62 | 2+00.0 Invert | 1001.1 | 45.1 | 38.4 | 30.2 | 44.1 | 37.9 | 29.1 |
| 63 | 1+00.0 Invert | 1000.9 | 39.8 | 34.7 | 27.9 | 41.6 | 35.3 | 27.8 |
| 64 | 0+00.0 Invert | 1000.8 | 38.1 | 32.5 | 26.6 | 39.2 | 34.2 | 26.7 |
| 65 | 1+00.0 Invert | 1000.6 | 31.9 | 28.6 | 24.9 | 34.6 | 30.7 | 25.4 |
| 66 | 2+00.0 Invert | 1000.4 | 29.4 | 26.9 | 23.6 | 32.6 | 29.6 | 24.3 |
| 67 | 3+00.0 Invert | 1000.2 | 24.5 | 23.3 | 21.8 | 28.8 | 26.8 | 23.3 |
| | Downstream Transition | | | | | | | |
| 68 | 3+23.0 Invert | 1000.2 | 22.1 | 21.2 | 20.6 | 26.8 | 25.1 | 23.3 |
| 69 | 3+23.0 Left Fillet | 1001.8 | 22.2 | 21.0 | 19.7 | 26.8 | 24.8 | 22.2 |

(Continued)

See Notes at end of table.

Table 4 (Continued)

| Piez No. | Piez Station and Location | Piez Zero | Right Gate Passage 3/4 Open Dischg, 21,750 Pool El, 1140.0 | Dischg, 19,100 Pool El, 1110.0 | Dischg, 14,250 Pool El, 1071.0 | Right Gate Passage 1/2 Open Dischg, 20,000 Pool El, 1140.0 | Dischg, 17,400 Pool El, 1110.0 | Dischg, 13,000 Pool El, 1071.0 |
|---|---|---|---|---|---|---|---|---|
| | | | | | Downstream Transition (Continued) | | | |
| 70 | 3+23.0 Left Side | 1010.2 | 12.9 | 12.1 | 10.8 | 18.0 | 15.8 | 12.6 |
| 71 | 3+23.0 Roof | 1020.2 | 1.6 | 1.1 | 0.3 | * | * | * |
| 72 | 3+23.0 Right Side | 1010.2 | 11.4 | 10.8 | 10.1 | 16.5 | 14.6 | 11.3 |
| 73 | 3+23.0 Right Fillet | 1001.8 | 18.4 | 18.2 | 18.0 | 23.2 | 22.1 | 19.4 |
| 74 | 3+43.0 Invert | 1000.2 | 22.1 | 21.5 | 20.5 | 27.1 | 25.1 | 21.8 |
| 75 | 3+43.0 Left Fillet | 1001.1 | 23.7 | 22.4 | 20.3 | 27.9 | 25.6 | 21.4 |
| 76 | 3+43.0 Left Side | 1010.2 | 12.6 | 11.8 | 10.7 | 17.0 | 15.3 | 12.0 |
| 77 | 3+43.0 Roof | 1020.2 | 2.8 | 1.8 | 0.7 | * | * | * |
| 78 | 3+43.0 Right Side | 1010.2 | 13.3 | 12.1 | 10.8 | 17.2 | 15.5 | 12.3 |
| 79 | 3+43.0 Right Fillet | 1001.1 | 20.5 | 19.9 | 19.2 | 24.9 | 23.5 | 20.6 |
| 80 | 3+63.0 Invert | 1000.1 | 18.7 | 18.8 | 19.1 | 24.1 | 23.1 | 21.1 |
| 81 | 3+63.0 Left Fillet | 1000.5 | 19.8 | 19.3 | 19.3 | 24.7 | 23.5 | 21.0 |
| 82 | 3+63.0 Left Side | 1010.1 | 10.7 | 10.1 | 9.9 | 15.7 | 14.4 | 11.5 |
| 83 | 3+63.0 Roof | 1020.1 | 0.1 | 0.5 | 0.0 | * | * | * |
| 84 | 3+63.0 Right Side | 1010.1 | 7.3 | 7.4 | 8.3 | 13.2 | 12.3 | 9.9 |
| 85 | 3+63.0 Right Fillet | 1000.5 | 15.8 | 16.2 | 17.7 | 21.5 | 21.3 | 19.2 |
| | | | | | Rectangular Conduit | | | |
| 86 | 4+00.0 Invert | 1000.1 | 13.4 | 14.6 | 16.7 | 19.4 | 19.6 | 18.7 |
| 87 | 4+90.0 Invert | 999.9 | 8.3 | 10.6 | 14.2 | 12.9 | 14.8 | 15.8 |

Notes: Pressures are recorded in prototype feet of water.
Discharges are recorded in cubic feet per second.
Pool elevations are recorded in feet above mean sea level.
All pressure measurements confined to right half of outlet structure.
*Piezometer is above water surface.

Table 5

PRESSURES THROUGHOUT OUTLET STRUCTURES, ORIGINAL DESIGN

Both Gate Passages Open as Shown

| Piez No. | Piez Station and Location | Piez Zero | Both Gate Passages 1/4 Open: Dischg, 6,400 Pool El, 1140.0 | Dischg, 5,600 Pool El, 1110.0 | Dischg, 4,400 Pool El, 1071.0 | Lt Gate Passage Open Full, Rt Gate Passage 1/4 Open: Dischg, 18,400 Pool El, 1140.0 | Dischg, 17,950 Pool El, 1110.0 | Dischg, 12,150 Pool El, 1071.0 |
|---|---|---|---|---|---|---|---|---|
| 1 | 4+03.5 Roof | 1031.3 | 108.3 | 77.7 | 39.4 | 82.9 | 58.4 | 29.4 |
| 2 | 4+02.5 Roof | 1028.2 | 110.6 | 80.1 | 42.3 | 72.7 | 51.3 | 27.3 |
| 3 | 4+01.5 Roof | 1026.9 | 110.7 | 80.8 | 43.0 | 47.7 | 33.5 | 16.7 |
| 4 | 4+00.5 Roof | 1025.3 | 112.1 | 81.9 | 44.3 | 41.9 | 29.6 | 14.9 |
| 5 | 3+98.5 Roof | 1024.2 | 113.1 | 82.9 | 45.2 | 38.6 | 27.2 | 13.5 |
| 6 | 3+96.5 Roof | 1023.1 | 113.9 | 83.8 | 46.3 | 29.4 | 20.5 | 10.1 |
| 7 | 3+94.5 Roof | 1022.6 | 114.0 | 83.9 | 46.5 | 17.1 | 11.7 | 5.4 |
| 8 | 3+92.5 Roof | 1022.1 | 114.4 | 84.3 | 46.9 | 14.9 | 10.4 | 4.8 |
| 9 | 3+90.5 Roof | 1021.8 | 114.7 | 84.6 | 47.2 | 11.4 | 8.0 | 3.4 |
| 10 | 3+88.5 Roof | 1021.5 | 115.0 | 84.9 | 47.5 | 8.0 | 5.3 | 2.0 |
| 11 | 3+86.5 Roof | 1021.4 | 115.3 | 85.1 | 47.7 | 8.6 | 5.6 | 2.1 |
| 12 | 3+84.5 Roof | 1021.3 | 115.5 | 85.2 | 47.9 | 16.7 | 11.7 | 5.5 |
| 13 | 4+03.5 Corner of Roof | 1031.3 | 108.3 | 77.7 | 39.2 | 84.0 | 59.7 | 29.4 |
| 14 | 4+02.5 Corner of Roof | 1028.2 | 109.9 | 80.3 | 42.1 | 75.0 | 53.8 | 28.6 |
| 15 | 4+01.5 Corner of Roof | 1026.9 | 110.9 | 80.8 | 42.8 | 46.9 | 33.8 | 16.6 |
| 16 | 4+00.5 Corner of Roof | 1025.3 | 112.3 | 82.2 | 44.3 | 41.7 | 29.9 | 15.3 |
| 17 | 3+98.5 Corner of Roof | 1024.2 | 113.2 | 83.2 | 45.3 | 38.6 | 27.8 | 14.5 |
| 18 | 3+96.5 Corner of Roof | 1023.1 | 113.9 | 84.1 | 46.2 | 28.6 | 20.3 | 10.3 |
| 19 | 3+94.5 Corner of Roof | 1022.6 | 114.1 | 84.4 | 46.6 | 19.6 | 13.6 | 6.9 |
| 20 | 3+92.5 Corner of Roof | 1022.1 | 114.3 | 84.7 | 46.9 | 14.7 | 9.9 | 5.4 |
| 21 | 3+90.5 Corner of Roof | 1021.8 | 114.6 | 85.1 | 47.2 | 9.7 | 6.2 | 2.5 |
| 22 | 3+88.5 Corner of Roof | 1021.5 | 115.0 | 85.4 | 47.5 | 7.7 | 4.8 | 2.0 |
| 23 | 3+86.5 Corner of Roof | 1021.4 | 115.1 | 85.7 | 47.8 | 8.2 | 5.3 | 2.1 |
| 24 | 3+84.5 Corner of Roof | 1021.3 | 115.7 | 86.2 | 48.0 | 15.0 | 12.1 | 6.2 |
| 25 | 3+74.5 Roof | 1021.3 | 118.7 | 87.3 | 49.3 | 19.5 | 14.7 | 8.2 |
| 26 | 3+49.5 Roof | 1021.3 | * | * | * | 20.2 | 14.3 | 9.1 |
| 27 | 3+29.5 Roof | 1021.3 | * | * | * | 20.3 | 14.4 | 7.0 |
| 28 | 4+29.3 Pier | 1011.3 | 128.7 | 98.7 | 59.7 | 115.7 | 88.7 | 53.9 |
| 29 | 4+27.3 Pier | 1011.3 | 128.7 | 98.7 | 59.7 | 117.5 | 90.2 | 54.9 |
| 30 | 4+23.3 Pier | 1011.3 | 128.7 | 98.7 | 59.7 | 116.7 | 88.4 | 54.3 |
| 31 | 4+15.3 Pier | 1011.3 | 128.7 | 98.7 | 59.7 | 113.6 | 86.9 | 53.0 |
| 32 | 4+09.3 Pier | 1011.3 | 128.4 | 98.3 | 59.6 | 106.2 | 81.5 | 49.9 |
| 33 | 3+98.5 Side | 1011.3 | 127.1 | 97.3 | 58.9 | 77.1 | 59.6 | 37.5 |
| 34 | 3+88.5 Side | 1011.3 | 125.7 | 96.3 | 58.3 | 44.4 | 35.5 | 23.9 |
| 35 | 3+74.5 Side | 1011.3 | 125.4 | 96.5 | 57.6 | 35.1 | 27.9 | 19.1 |
| 36 | 3+49.5 Side | 1011.3 | * | * | * | 30.2 | 24.4 | 17.0 |
| 37 | 3+29.5 Side | 1011.3 | * | * | * | 24.7 | 20.7 | 14.9 |
| 38 | 3+98.5 Invert | 1001.3 | 137.5 | 107.6 | 68.9 | 89.5 | 71.5 | 48.7 |
| 39 | 3+88.5 Invert | 1001.3 | 135.8 | 106.5 | 68.2 | 61.2 | 50.4 | 36.7 |
| 40 | 3+58.5 Invert | 1001.3 | 9.0 | 9.0 | 7.2 | 40.5 | 34.9 | 27.4 |
| 41 | 3+29.5 Invert | 1001.3 | 3.7 | 3.4 | 3.7 | 37.0 | 32.0 | 26.0 |
| | | | | | Intake Transition | | | |
| 42 | 3+17.0 Invert | 1001.3 | 4.7 | 4.7 | 4.5 | 38.5 | 33.2 | 26.4 |
| 43 | 3+17.0 Left Fillet | 1001.8 | 5.5 | 5.5 | 5.7 | 40.2 | 34.4 | 26.7 |
| 44 | 3+17.0 Left Side | 1011.3 | * | * | * | 31.3 | 24.7 | 17.2 |
| 45 | 3+17.0 Left Fillet | 1020.5 | * | * | * | 22.2 | 17.0 | 9.1 |
| 46 | 3+17.0 Roof | 1021.3 | * | * | * | 17.5 | 13.2 | 6.7 |
| 47 | 2+97.4 Invert | 1001.3 | 4.9 | 4.9 | 5.0 | 22.9 | 20.9 | 18.9 |
| 48 | 2+97.4 Left Fillet | 1002.7 | 4.6 | 4.8 | 4.4 | 23.6 | 21.4 | 18.6 |
| 49 | 2+97.4 Left Side | 1011.3 | * | * | * | 15.2 | 12.9 | 10.0 |
| 50 | 2+97.4 Left Fillet | 1019.2 | * | * | * | 4.8 | 3.3 | 1.8 |
| 51 | 2+97.4 Roof | 1021.3 | * | * | * | -0.3 | -0.5 | -0.6 |
| 52 | 2+77.1 Invert | 1001.6 | 1.4 | 1.9 | 3.2 | 1.4 | 3.2 | 9.0 |
| 53 | 2+77.1 Left Fillet | 1003.0 | 2.2 | 2.6 | 3.2 | 2.5 | 5.0 | 9.8 |
| 54 | 2+77.1 Left Side | 1011.2 | * | * | * | -0.6 | 1.3 | 4.1 |
| 55 | 2+77.1 Left Fillet | 1018.7 | * | * | * | -8.6 | -6.1 | -2.2 |
| 56 | 2+77.1 Roof | 1021.2 | * | * | * | * | * | * |
| 57 | 2+98.7 Pier | 1016.3 | * | * | * | -4.5 | -2.8 | 0.4 |
| 58 | 2+90.5 Pier | 1011.3 | * | * | * | -3.1 | -1.7 | 0.7 |
| 59 | 2+82.2 Pier | 1006.2 | * | * | * | -4.2 | -1.4 | 1.5 |
| 60 | 2+90.5 Left Side | 1011.3 | * | * | * | 5.7 | 7.3 | 6.9 |
| | | | | | Horseshoe Conduit | | | |
| 61 | 2+50.0 Invert | 1001.2 | 6.3 | 5.5 | 6.1 | 14.0 | 16.8 | 16.6 |
| 62 | 2+00.0 Invert | 1001.1 | 5.5 | 5.6 | 5.5 | 13.9 | 13.5 | 12.9 |
| 63 | 1+00.0 Invert | 1000.9 | 5.2 | 5.6 | 5.6 | 13.1 | 13.8 | 13.3 |
| 64 | 0+00.0 Invert | 1000.8 | 6.5 | 6.7 | 6.4 | 15.2 | 15.2 | 15.2 |
| 65 | 1+00.0 Invert | 1000.6 | 5.6 | 6.4 | 6.6 | 13.7 | 14.2 | 15.6 |
| 66 | 2+00.0 Invert | 1000.4 | 7.8 | 7.7 | 6.9 | 16.8 | 16.7 | 16.4 |
| 67 | 3+00.0 Invert | 1000.2 | 6.8 | 6.8 | 6.9 | 16.0 | 16.0 | 16.8 |

(Continued)

See Notes at end of table.

Table 5 (Continued)

| Piez No. | Piez Station and Location | Piez Zero | Both Gate Passages 1/4 Open: Dischg, 6,400 Pool El, 1140.0 | Dischg, 5,600 Pool El, 1110.0 | Dischg, 4,400 Pool El, 1071.0 | Lt Gate Passage Open Full, Rt Gate Passage 1/4 Open: Dischg, 18,400 Pool El, 1140.0 | Dischg, 17,950 Pool El, 1110.0 | Dischg, 12,150 Pool El, 1071.0 |
|---|---|---|---|---|---|---|---|---|
| | | | | | Downstream Transition | | | |
| 68 | 3+23.0 Invert | 1000.2 | 7.0 | 6.9 | 6.9 | 15.9 | 16.0 | 17.3 |
| 69 | 3+23.0 Left Fillet | 1001.8 | 6.5 | 6.3 | 6.3 | 16.6 | 15.8 | 16.3 |
| 70 | 3+23.0 Left Side | 1010.2 | * | * | * | 8.1 | 6.5 | 7.8 |
| 71 | 3+23.0 Roof | 1020.2 | * | * | * | * | * | * |
| 72 | 3+23.0 Right Side | 1010.2 | * | * | * | 5.4 | 6.6 | 7.5 |
| 73 | 3+23.0 Right Fillet | 1001.8 | 4.4 | 4.2 | 4.7 | 12.2 | 13.5 | 15.2 |
| 74 | 3+43.0 Invert | 1001.2 | 7.6 | 7.3 | 7.4 | 17.8 | 17.9 | 18.7 |
| 75 | 3+43.0 Left Fillet | 1001.1 | 8.8 | 7.8 | 7.3 | 19.8 | 18.7 | 18.7 |
| 76 | 3+43.0 Left Side | 1010.2 | * | * | * | 8.3 | 7.7 | 9.0 |
| 77 | 3+43.0 Roof | 1020.2 | * | * | ** | * | * | * |
| 78 | 3+43.0 Right Side | 1010.2 | * | * | * | 7.3 | 8.3 | 8.6 |
| 79 | 3+43.0 Right Fillet | 1001.1 | 5.1 | 5.1 | 5.7 | 16.1 | 16.6 | 17.4 |
| 80 | 3+63.0 Invert | 1000.1 | 7.1 | 6.7 | 5.8 | 16.9 | 17.1 | 18.8 |
| 81 | 3+63.0 Left Fillet | 1000.5 | 7.6 | 7.0 | 6.7 | 17.7 | 17.7 | 18.7 |
| 82 | 3+63.0 Left Side | 1010.1 | * | * | * | 8.5 | 8.1 | 9.3 |
| 83 | 3+63.0 Roof | 1020.1 | * | * | * | * | * | * |
| 84 | 3+63.0 Right Side | 1010.1 | * | * | * | 6.7 | 6.4 | 8.0 |
| 85 | 3+63.0 Right Fillet | 1000.5 | 4.2 | 5.8 | 6.2 | 14.7 | 15.6 | 17.7 |
| | | | | | Rectangular Conduit | | | |
| 86 | 4+00.0 Invert | 1000.1 | 6.6 | 6.7 | 7.0 | 16.4 | 16.9 | 19.4 |
| 87 | 4+90.0 Invert | 999.9 | 7.2 | 7.7 | 7.7 | 12.9 | 13.9 | 16.1 |

Notes: Pressures are recorded in prototype feet of water.
Discharges are recorded in cubic feet per second.
Pool elevations are recorded in feet above mean sea level.
All pressure measurements confined to right half of outlet structure.
*Piezometer is above water surface.

Table 6

GATE SLOT PRESSURES IN RIGHT PASSAGE OF RIGHT CONDUIT

ORIGINAL DESIGN

Left Gate Passage Open Full,
Right Gate Passage Open As Shown

| Piez No. | Piez Zero | Full Gate Opening Pool Elevations | | | 3/4 Gate Opening Pool Elevations | | | 1/2 Gate Opening Pool Elevations | | | 1/4 Gate Opening Pool Elevations | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1140.0 | 1110.0 | 1071.0 | 1140.0 | 1110.0 | 1071.0 | 1140.0 | 1110.0 | 1071.0 | 1140.0 | 1110.0 | 1071.0 |
| 1 | 1003.8 | 93.7 | 73.7 | 48.9 | 82.2 | 65.2 | 42.7 | 77.2 | 60.7 | 38.2 | 43.2 | 34.2 | 25.2 |
| 2 | 1006.3 | 89.7 | 70.2 | 46.3 | 78.7 | 61.7 | 39.7 | 67.2 | 53.7 | 34.7 | * | * | * |
| 3 | 1008.8 | 87.7 | 67.2 | 43.7 | 73.2 | 57.2 | 36.8 | * | * | * | * | * | * |
| 4 | 1011.3 | 84.2 | 64.2 | 40.5 | 64.7 | 51.7 | 32.7 | * | * | * | * | * | * |
| 5 | 1013.8 | 81.7 | 61.2 | 37.7 | 31.2 | 23.7 | 15.2 | * | * | * | * | * | * |
| 6 | 1016.3 | 76.2 | 58.2 | 34.2 | 3.7 | 3.7 | 3.2 | * | * | * | * | * | * |
| 7 | 1006.3 | 88.7 | 68.2 | 45.0 | 70.2 | 56.2 | 35.4 | 55.7 | 44.2 | 29.7 | * | * | * |
| 8 | 1011.3 | 82.2 | 62.7 | 39.5 | 54.2 | 42.7 | 27.2 | * | * | * | * | * | * |
| 9 | 1016.3 | 76.2 | 56.7 | 33.5 | 4.7 | 4.2 | 3.7 | * | * | * | * | * | * |
| 10 | 1006.3 | 81.2 | 63.7 | 42.2 | 53.5 | 44.4 | 29.7 | 26.5 | 25.7 | 18.2 | * | * | * |
| 11 | 1011.3 | 75.7 | 57.7 | 36.9 | 32.7 | 27.7 | 19.0 | * | * | * | * | * | * |
| 12 | 1016.3 | 70.7 | 53.0 | 32.0 | 4.7 | 4.7 | 4.2 | * | * | * | * | * | * |
| 13 | 1011.3 | 75.7 | 57.9 | 37.0 | 83.7 | 64.7 | 40.3 | 110.7 | 84.2 | 50.5 | 125.7 | 96.7 | 58.2 |
| 14 | 1011.3 | 73.2 | 56.0 | 35.9 | 22.2 | 19.0 | 14.2 | * | * | * | * | * | * |
| 15 | 1001.3 | 84.2 | 66.9 | 46.2 | 49.2 | 41.7 | 31.2 | 32.2 | 26.7 | 20.5 | 9.2 | 8.2 | 6.7 |

Notes: Pressures are recorded in prototype feet of water.
Pool elevations are recorded in feet above mean sea level.
*Piezometer is above water surface.

Table 7

GATE SLOT PRESSURES IN RIGHT PASSAGE OF RIGHT CONDUIT, ORIGINAL DESIGN

Various Gate Openings

| Piez No. | Piez Zero | Left Gate Passage Closed, Right Gate Passage Open as Shown** | | | | | | Both Gate Passages Open as Shown** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Full Gate Opening Pool Elevations | | | 3/4 Gate Opening Pool Elevations | | | 3/4 Gate Opening Pool Elevations | | |
| | | 1140.0 | 1110.0 | 1071.0 | 1140.0 | 1110.0 | 1071.0 | 1140.0 | 1110.0 | 1071.0 |
| 1 | 1003.8 | 64.7 | 51.7 | 35.2 | 77.2 | 61.0 | 39.5 | 79.7 | 63.2 | 39.7 |
| 2 | 1006.3 | 59.7 | 48.2 | 32.4 | 73.2 | 58.0 | 36.7 | 75.2 | 60.2 | 36.2 |
| 3 | 1008.8 | 55.7 | 44.2 | 29.5 | 67.7 | 54.2 | 33.7 | 71.7 | 56.2 | 33.2 |
| 4 | 1011.3 | 52.9 | 40.7 | 26.3 | 53.7 | 43.7 | 27.2 | 59.2 | 47.7 | 29.7 |
| 5 | 1013.8 | 49.7 | 37.2 | 23.4 | 17.7 | 11.2 | 7.2 | 21.2 | 14.2 | 9.2 |
| 6 | 1016.3 | 44.2 | 33.2 | 20.2 | * | * | * | * | * | * |
| 7 | 1006.3 | 54.7 | 44.2 | 30.7 | 62.7 | 50.7 | 32.2 | 67.7 | 53.7 | 35.2 |
| 8 | 1011.3 | 47.7 | 37.2 | 24.9 | 45.2 | 36.7 | 22.2 | 47.7 | 38.7 | 25.7 |
| 9 | 1016.3 | 40.5 | 30.9 | 18.7 | * | * | * | * | * | * |
| 10 | 1006.3 | 42.7 | 35.4 | 25.5 | 46.2 | 37.7 | 25.0 | 50.2 | 40.7 | 28.5 |
| 11 | 1011.3 | 36.2 | 29.2 | 19.9 | 23.7 | 19.2 | 12.9 | 27.2 | 22.5 | 15.2 |
| 12 | 1016.3 | 32.2 | 24.9 | 15.2 | * | * | * | * | * | * |
| 13 | 1011.3 | 36.5 | 29.3 | 19.9 | 81.7 | 62.2 | 38.0 | 83.2 | 64.7 | 39.7 |
| 14 | 1011.3 | 32.2 | 26.1 | 17.9 | 11.7 | 9.7 | 7.2 | 15.7 | 13.7 | 10.7 |
| 15 | 1001.3 | 43.2 | 37.2 | 28.7 | 40.7 | 34.2 | 24.9 | 45.2 | 38.2 | 29.2 |

Notes: Pressures are recorded in prototype feet of water.
Pool elevations are recorded in feet above mean sea level.
*Piezometer is above water surface.
**Pressures for 1/2- and 1/4-gate opening are identical to those shown in table 6.

Table 8

PRESSURES IN CONTROL GATE WELL

ORIGINAL DESIGN

| Piez No. | Piez Location | Piez Zero | Pool Elevations 1140.0 | Pool Elevations 1110.0 | Pool Elevations 1071.0 | Pool Elevations 1140.0 | Pool Elevations 1110.0 | Pool Elevations 1071.0 | Pool Elevations 1140.0 | Pool Elevations 1110.0 | Pool Elevations 1071.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Left Gate Open 20 Ft (Full) - Right Gate Open as Shown | | | | | | | | |
| | | | 20 Ft (Full) | | | 18 Ft | | | 16 Ft | | |
| 1 | Upstream | 1027.6 | 56.6 | 41.1 | 19.7 | 25.4 | 17.4 | 13.0 | 3.4 | 6.9 | 10.7 |
| 2 | Downstream | 1027.6 | 57.9 | 42.0 | 20.2 | 33.9 | 23.4 | 9.4 | 12.4 | ---- | ---- |
| 3 | Upstream | 1040.1 | 45.4 | 29.5 | 7.7 | 21.4 | 10.9 | 2.4 | 4.9 | 4.9 | 1.6 |
| 4 | Downstream | 1040.1 | 45.4 | 29.5 | 7.7 | 21.4 | 10.9 | ---- | ---- | ---- | ---- |
| | | | Left Gate Closed Right Gate Open 20 Ft (Full) | | | Both Gates Open as Shown | | | | | |
| | | | | | | 18 Ft | | | 16 Ft | | |
| 1 | Upstream | 1027.6 | 15.7 | 14.9 | 13.7 | 17.9 | 12.2 | 12.6 | 3.6 | 7.1 | 10.9 |
| 2 | Downstream | 1027.6 | 18.0 | 10.9 | 0.1 | 27.4 | 18.9 | 6.9 | 7.4 | ---- | ---- |
| 3 | Upstream | 1040.1 | 5.5 | 3.6 | 1.2 | 14.9 | 6.4 | 2.4 | 2.2 | 1.9 | 1.1 |
| 4 | Downstream | 1040.1 | 5.5 | ---- | ---- | 14.9 | 6.7 | ---- | ---- | ---- | ---- |

Notes: Piezometers located along center line of walls in right gate well.
Pressures are recorded in prototype feet of water.
Pool elevations are recorded in feet above mean sea level.

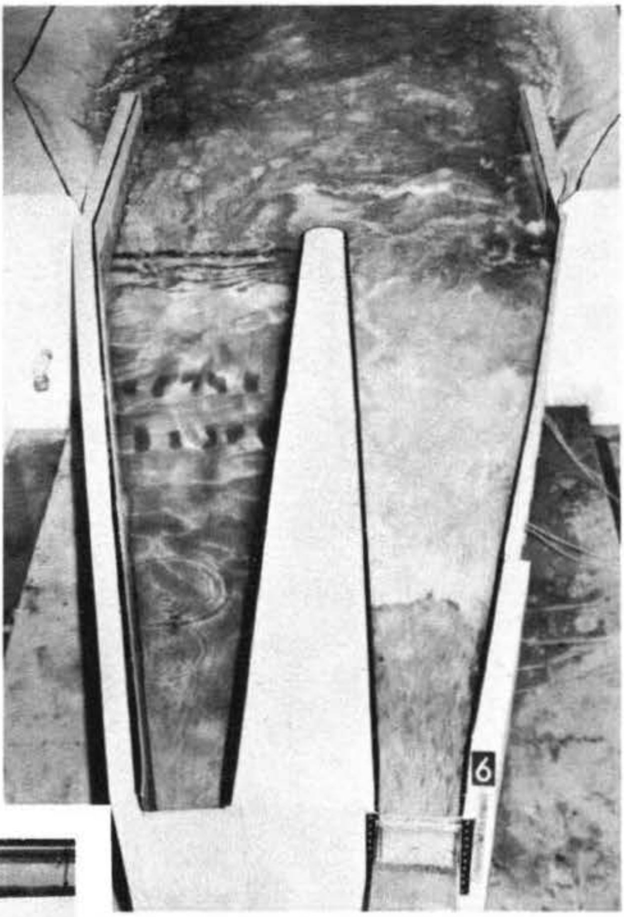
Table 9

BAFFLE PIER PRESSURES

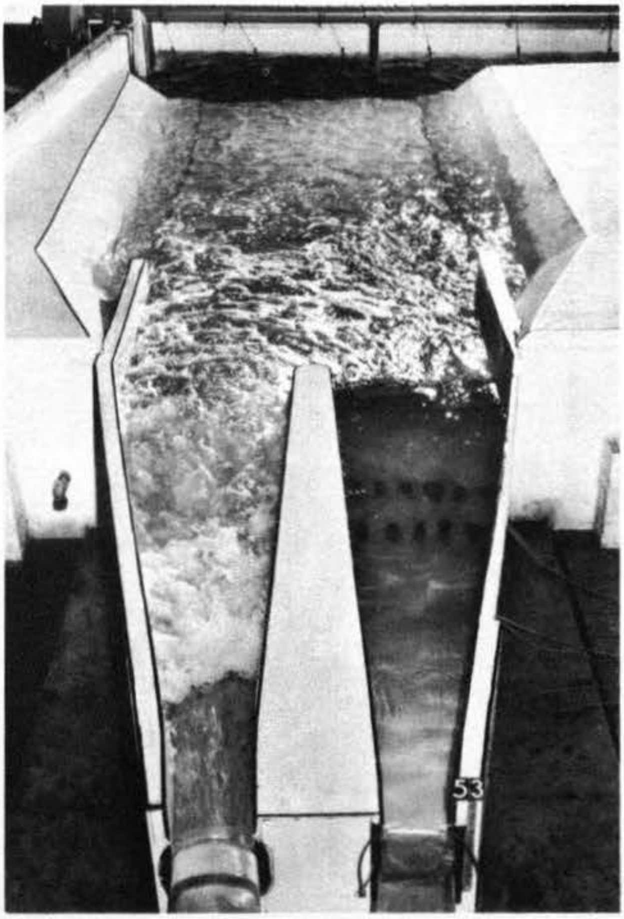
ALTERNATE BASIN DESIGN

| Piez No. | Piez Zero | Full Gate Opening Discharge 22,500 | | Full Gate Opening Discharge 20,000 | | Full Gate Opening Discharge 15,000 | |
|---|---|---|---|---|---|---|---|
| | | Pool Elev, 1125.0 Tailwater Elev, 1020.0 | Pool Elev, 1125.0 Tailwater Elev, 1017.0 | Pool Elev, 1110.0 Tailwater Elev, 1019.0 | Pool Elev, 1110.0 Tailwater Elev, 1016.0 | Pool Elev, 1071.0 Tailwater Elev, 1017.5 | Pool Elev, 1071.0 Tailwater Elev, 1014.5 |
| 1 | 981.4 | 66.6 | 66.6 | 62.6 | 63.6 | 49.6 | 48.6 |
| 2 | 985.5 | -0.5 | -7.0 | 3.0 | -2.5 | 15.5 | 11.0 |
| 3 | 985.5 | -3.5 | -7.5 | 1.5 | -4.0 | 15.5 | 11.0 |
| 4 | 985.5 | -2.5 | -8.5 | 1.5 | -4.0 | 14.5 | 9.5 |
| 5 | 984.9 | 8.1 | 2.1 | 11.1 | 6.1 | 20.1 | 17.1 |
| 6 | 981.3 | -14.3 | -23.8 | -11.3 | -17.3 | 12.7 | 4.7 |
| 7 | 981.3 | 1.7 | -6.8 | 3.7 | -5.3 | 16.7 | 13.2 |
| 8 | 981.3 | 13.2 | 7.2 | 15.2 | 10.7 | 24.7 | 20.2 |
| 9 | 981.3 | 20.7 | 15.2 | 22.2 | 17.2 | 28.2 | 24.2 |
| 10 | 977.6 | -12.6 | -25.6 | -11.6 | -18.6 | 14.4 | 7.4 |
| 11 | 984.9 | -12.9 | -19.9 | -7.9 | -13.9 | 12.1 | 6.1 |

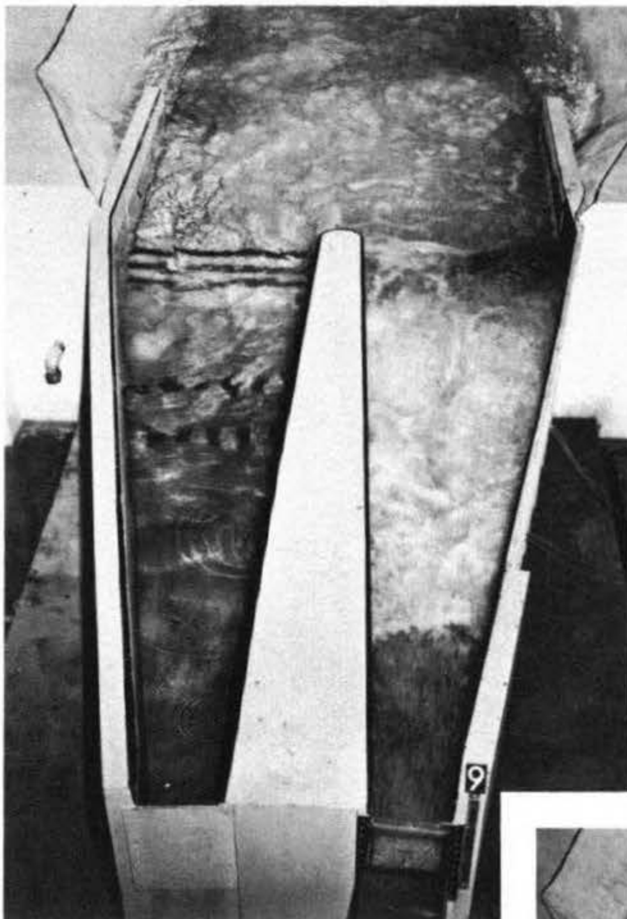
Notes: Pressures are recorded in prototype feet of water.
Discharges are recorded in cubic feet per second.
Pool and tailwater elevations are recorded in feet above mean sea level.



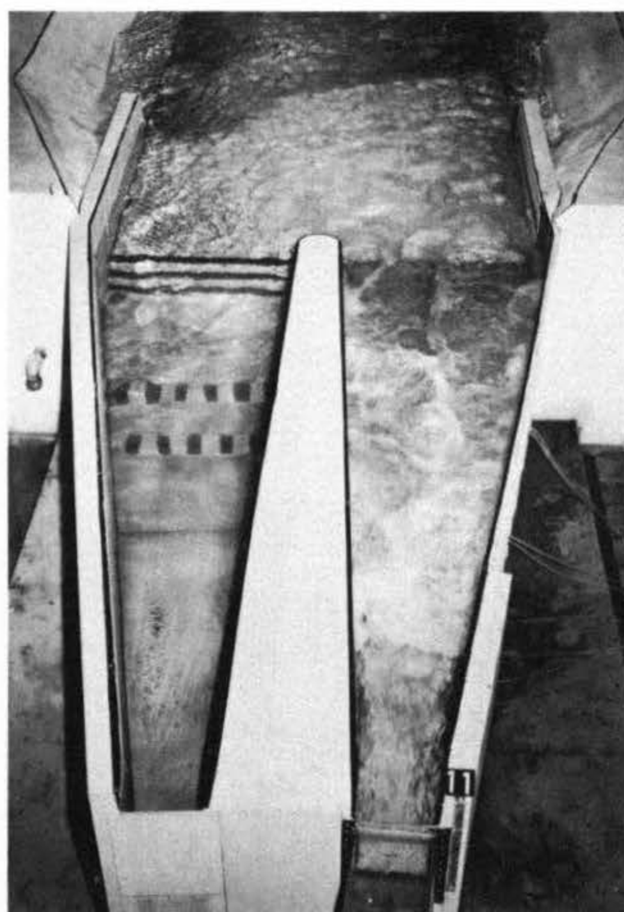

Photograph 1. Original stilling basin. Right rectangular conduit at full gate opening. Discharge 22,500 cfs, tailwater el 1017.0



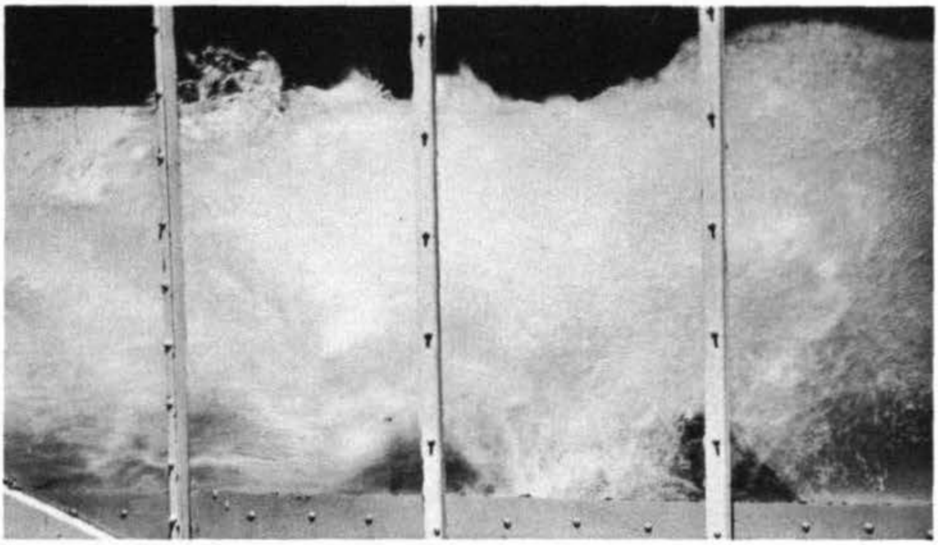

Photograph 2. Original stilling basin. Left horseshoe-shaped conduit at full gate opening. Discharge 22,500 cfs, tailwater el 1017.0



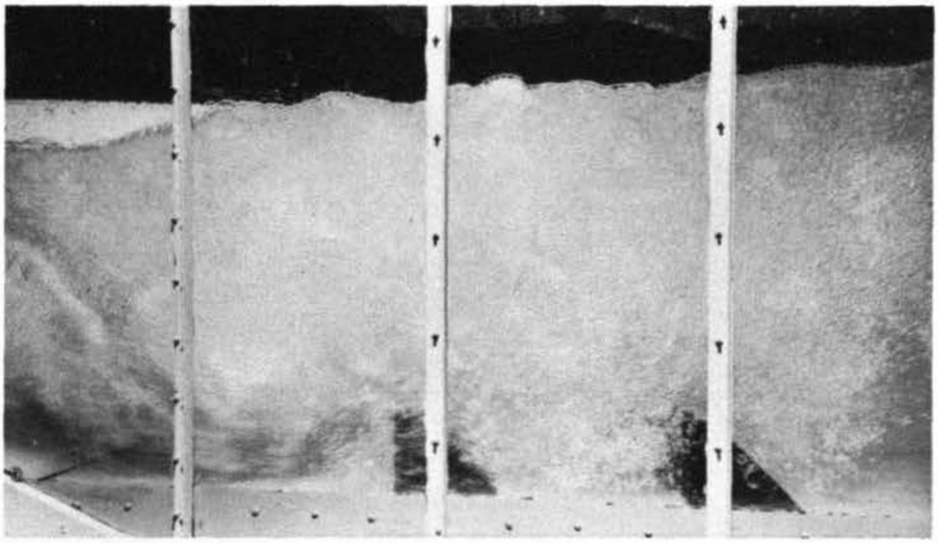
Photograph 3. Original stilling basin. Right rectangular conduit at full gate opening. Discharge 20,000 cfs, tailwater el 1016.0



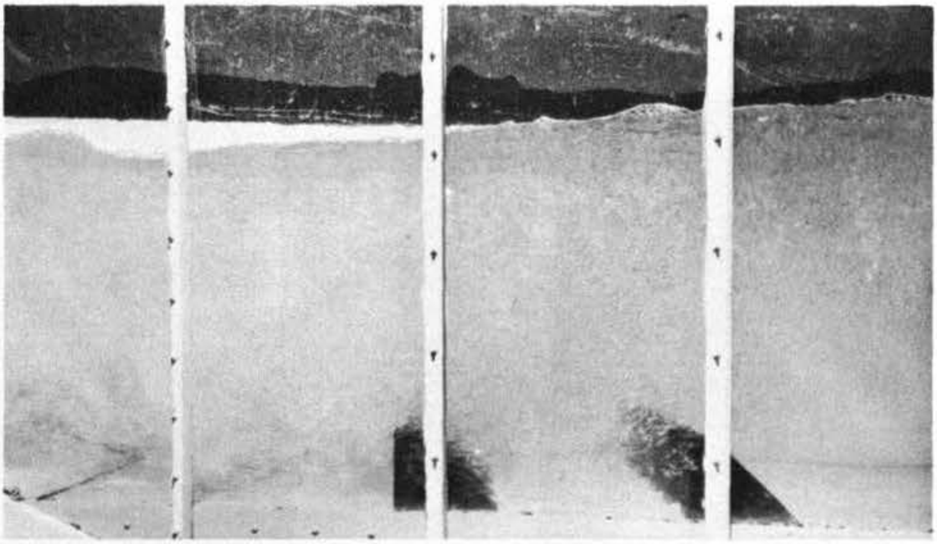
Photograph 4. Original stilling basin. Right rectangular conduit at full gate opening. Discharge 15,000 cfs, tailwater el 1014.5



Photograph 5. Original stilling basin. Discharge, 22,500 cfs (full gate opening). Tailwater, el 1017.0

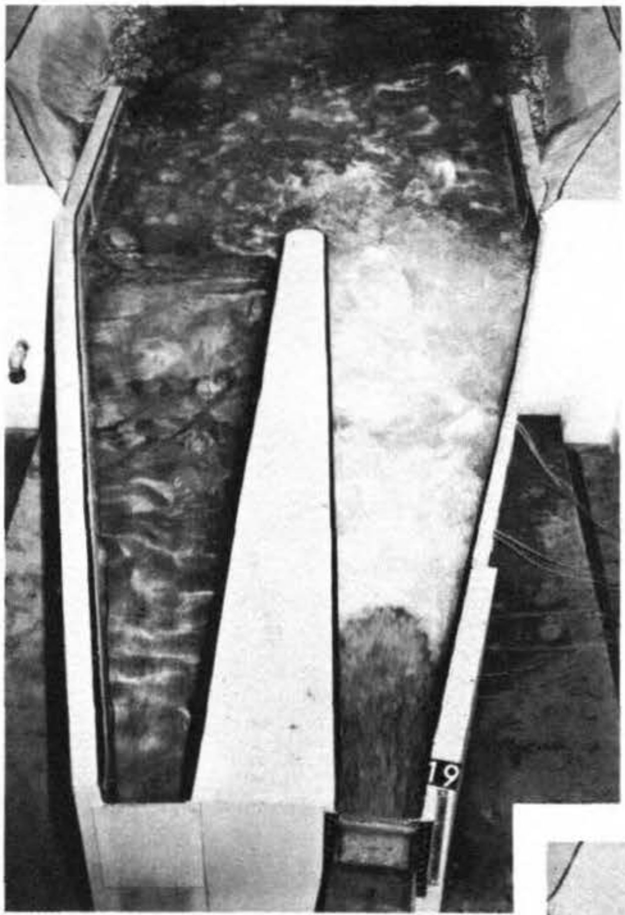


Photograph 6. Original stilling basin. Discharge, 15,000 cfs (full gate opening). Tailwater, el 1014.5

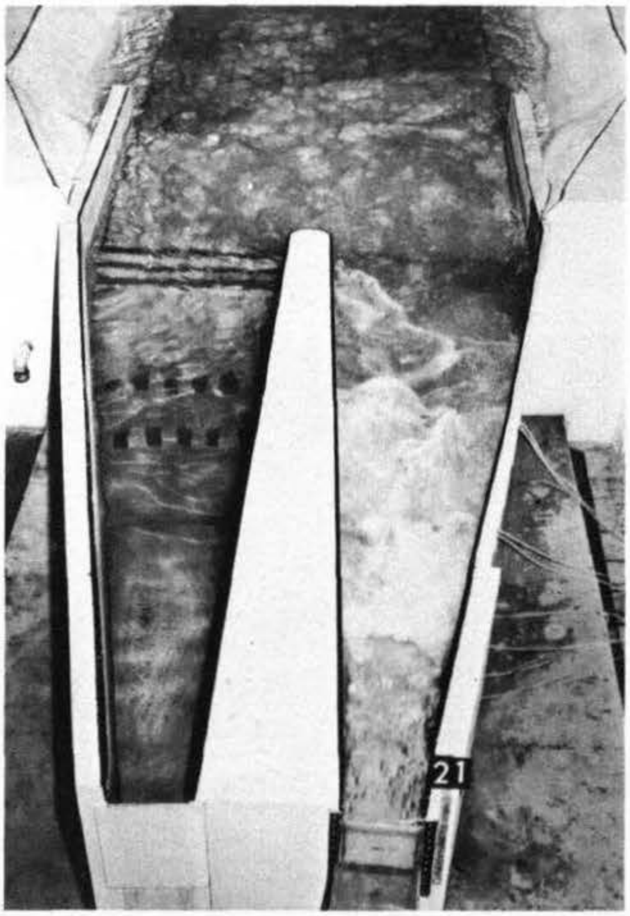


Photograph 7. Original stilling basin. Discharge, 10,000 cfs (full gate opening). Tailwater, el 1012.5

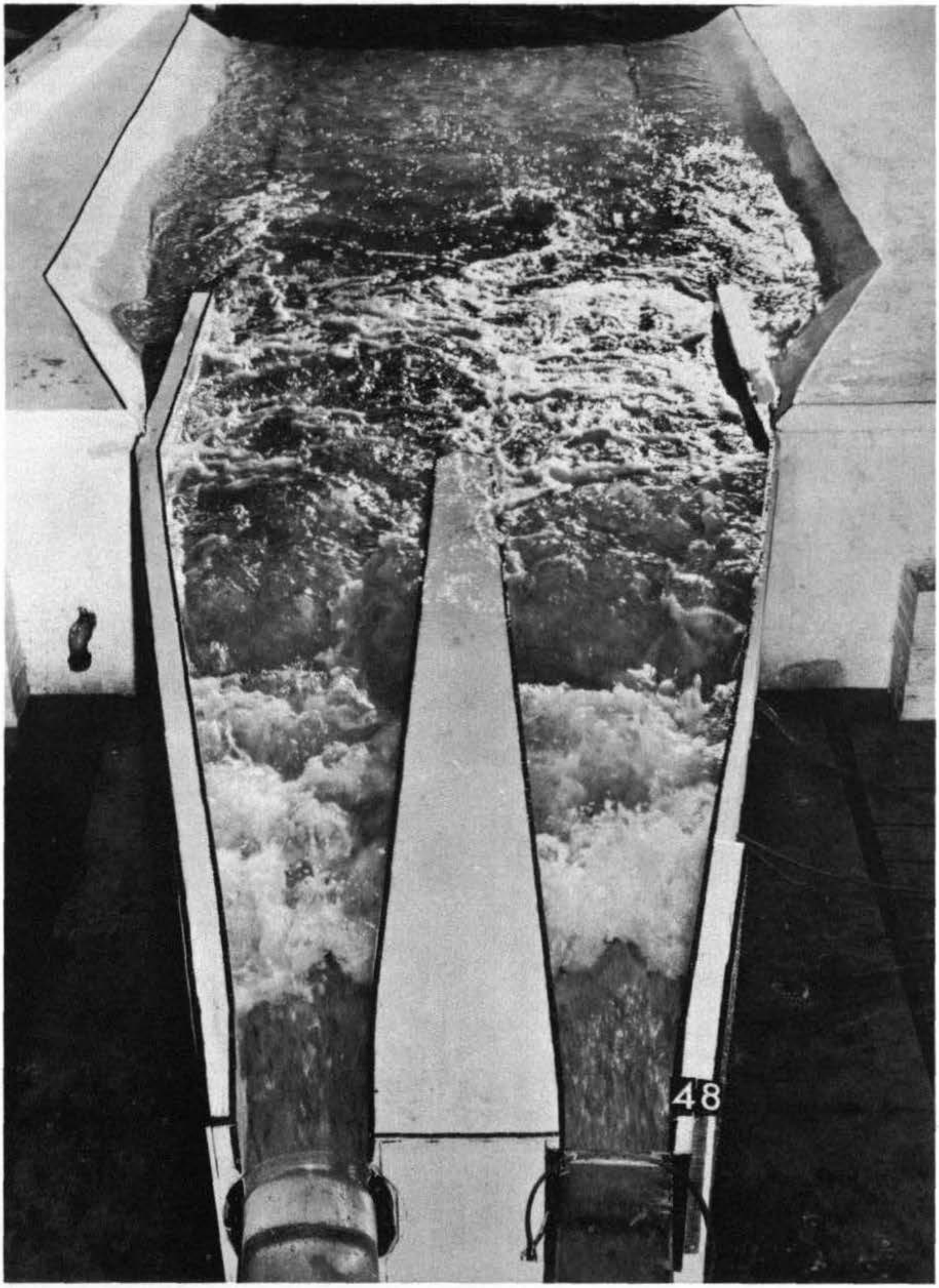
Flow conditions as seen through plastic window in right basin wall



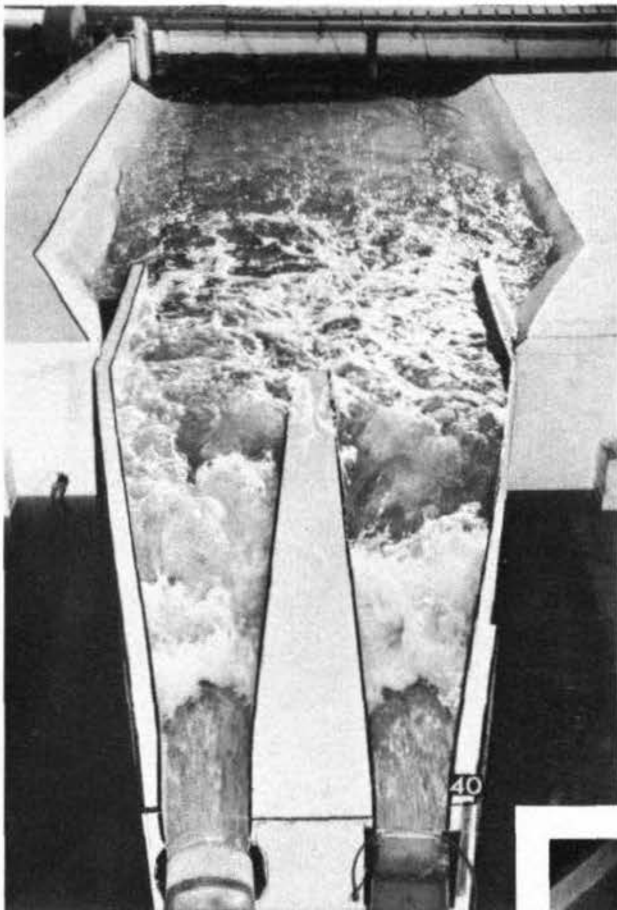

Photograph 8. Action in original-design stilling basin with baffle piers removed from right basin. Full gate opening; discharge 22,500 cfs, tailwater el 1017.0



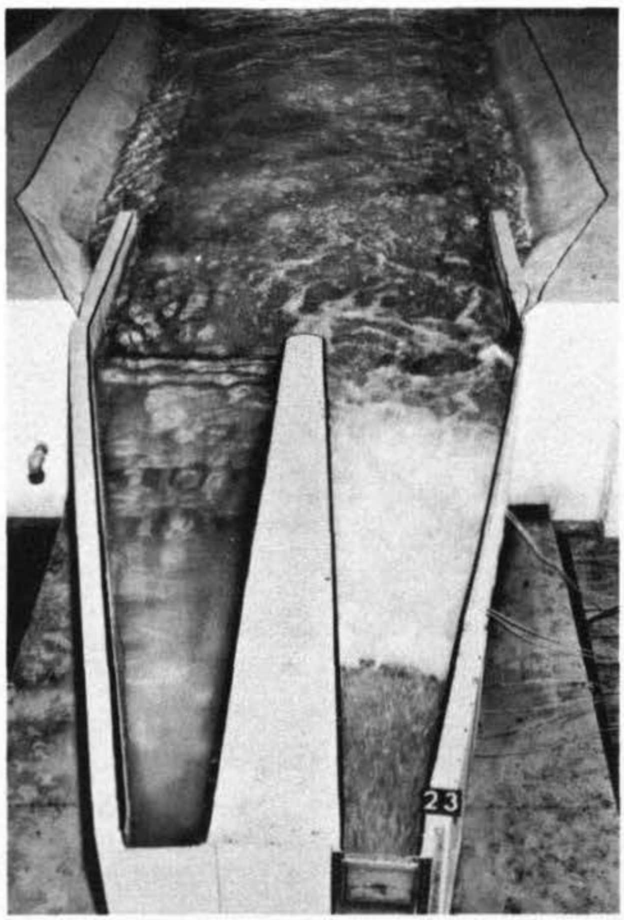

Photograph 9. Action in original-design stilling basin with baffle piers removed from right basin. Full gate opening; discharge 15,000 cfs, tailwater el 1014.5



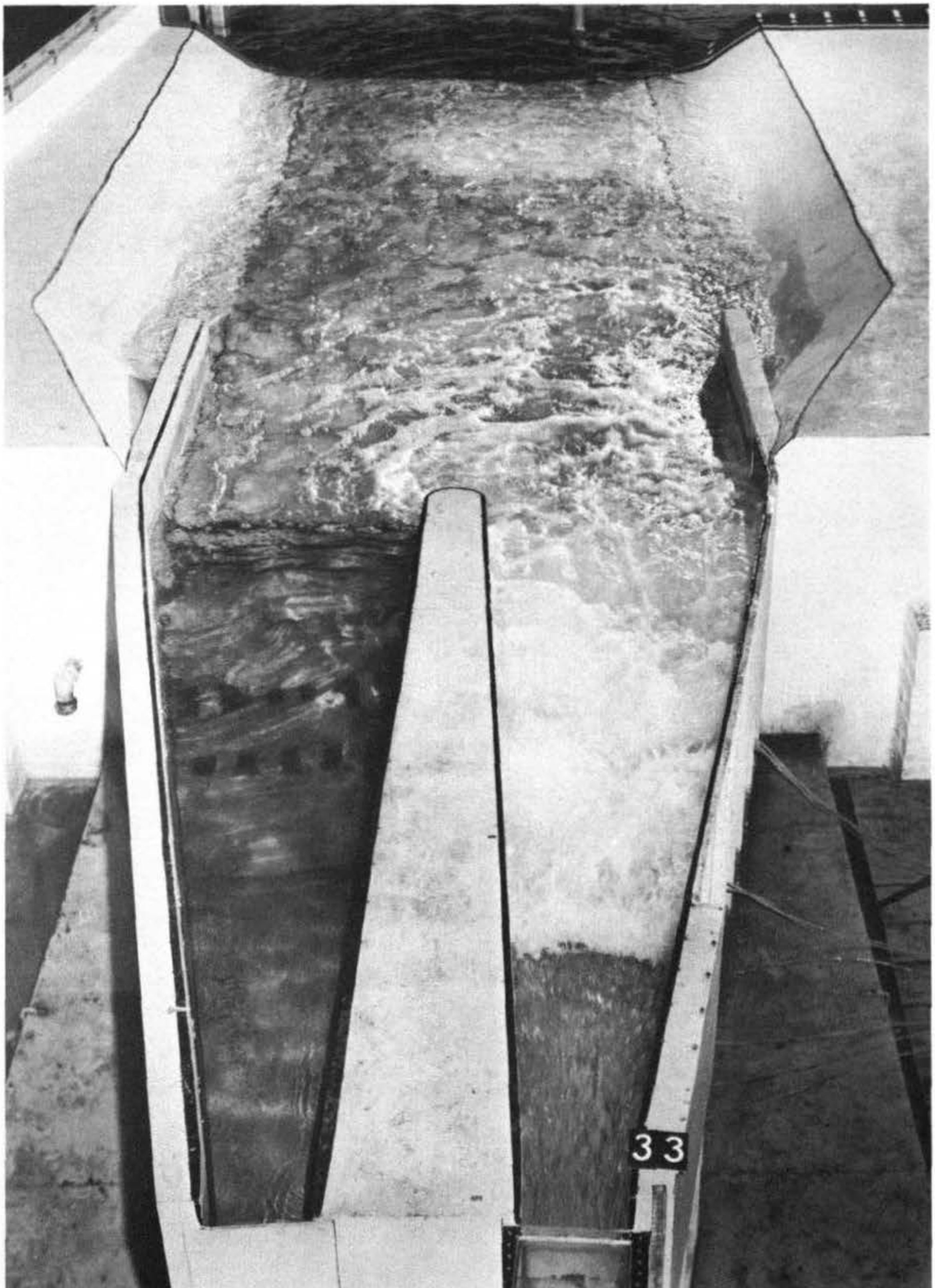

Photograph 10. Original stilling basin. Right rectangular conduit and left horseshoe-shaped conduit each discharging 22,500 cfs, tailwater el 1022.2



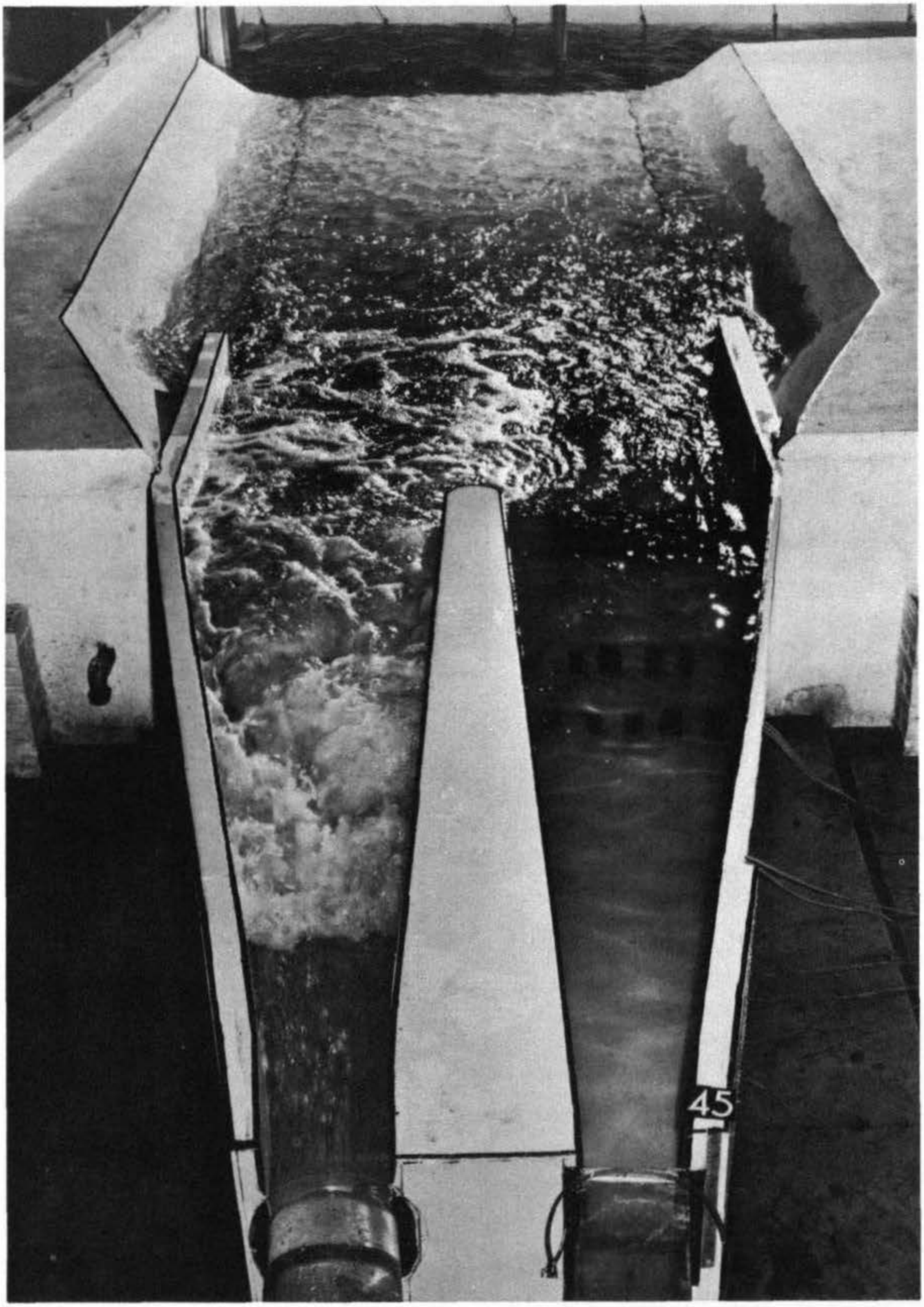

Photograph 11. Stilling basin floor raised 5 ft to el 977. Baffle piers at sta 6+61.4 and 6+96.4. Right rectangular conduit and left horseshoe-shaped conduit each discharging 22,500 cfs; tailwater el 1022.2



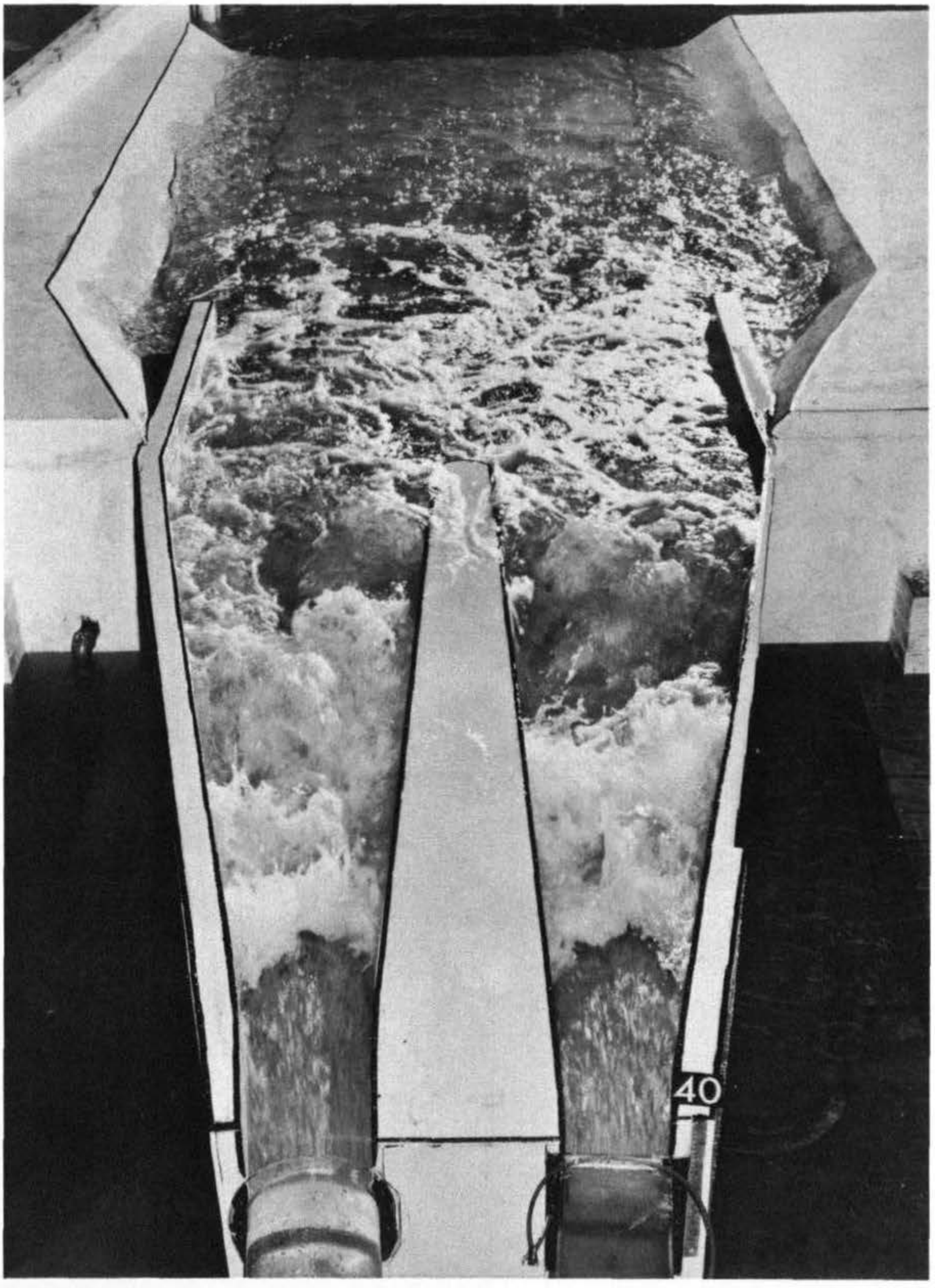

Photograph 12. Stilling basin floor raised 5 ft to el 977. Baffle piers at sta 6+61.4 and 6+96.4. Right rectangular conduit discharging 22,500 cfs; tailwater el 1017.0



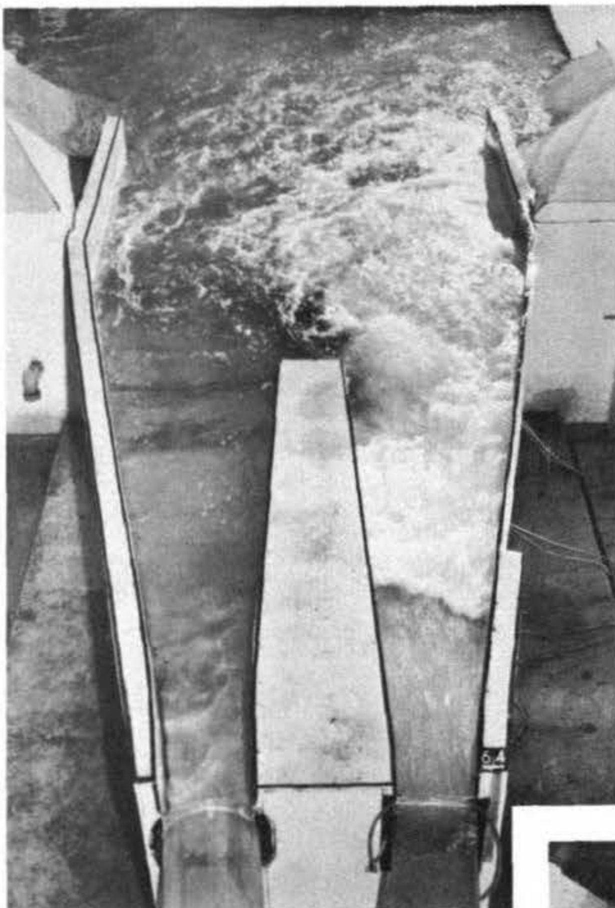

Photograph 13. Stilling basin floor raised to el 977.0. Baffle piers at sta 6+85.4 and 7+15.4. Right rectangular conduit at full gate opening. Discharge 22,500 cfs, tailwater el 1017.0



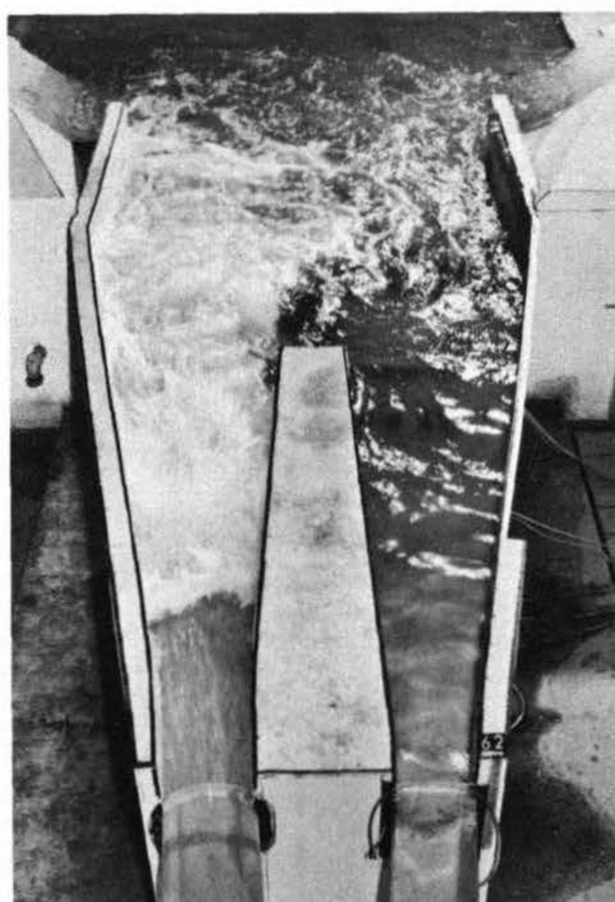

Photograph 14. Alternate basin design 1. Apron at el 977.0 and baffle piers at sta 6+76 and 7+06. Left horseshoe-shaped conduit at full gate opening. Discharge 22,500 cfs, tailwater el 1017.0



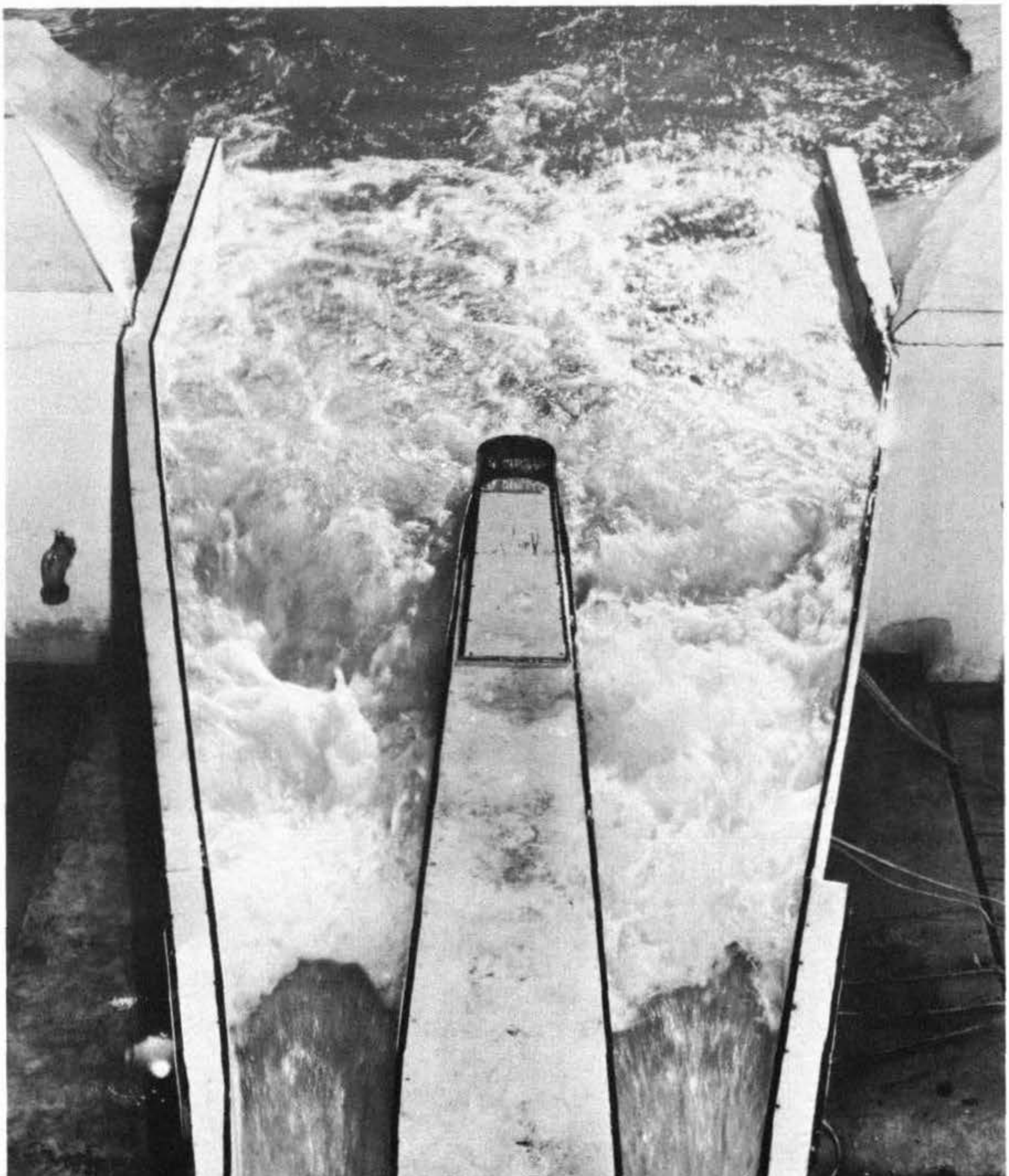

Photograph 15. Flow through both conduits. Alternate basin design 1. Apron at el 977.0 and baffle piers at sta 6+76 and 7+06. Discharge 45,000 cfs, tailwater el 1022.2



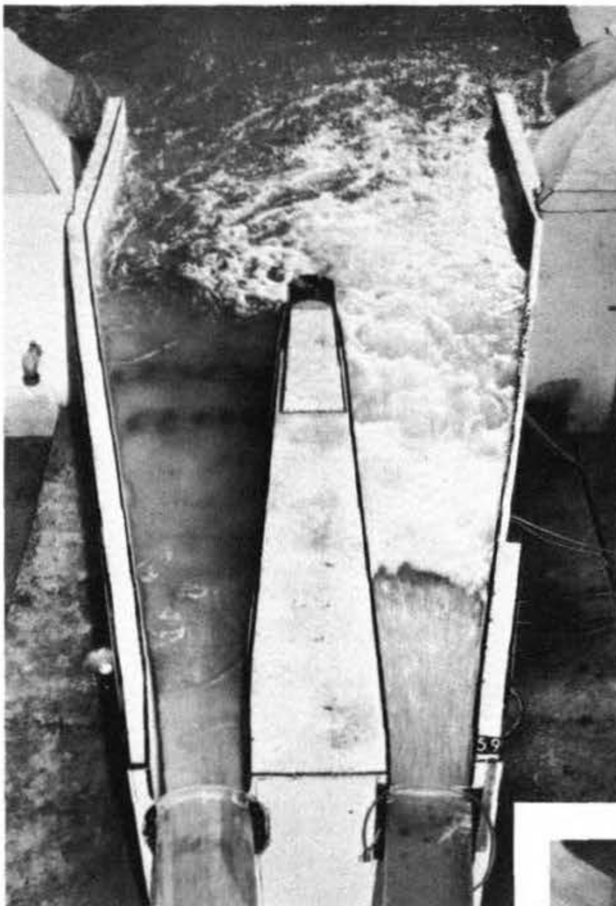
Photograph 16. Flow through right rectangular conduit with stilling basin raised to el 977.0, end sill (sta 7+86) and exit channel at el 995.0. Pier length shortened 91 ft (sta 6+76). Discharge 22,500 cfs, tailwater el 1017.0



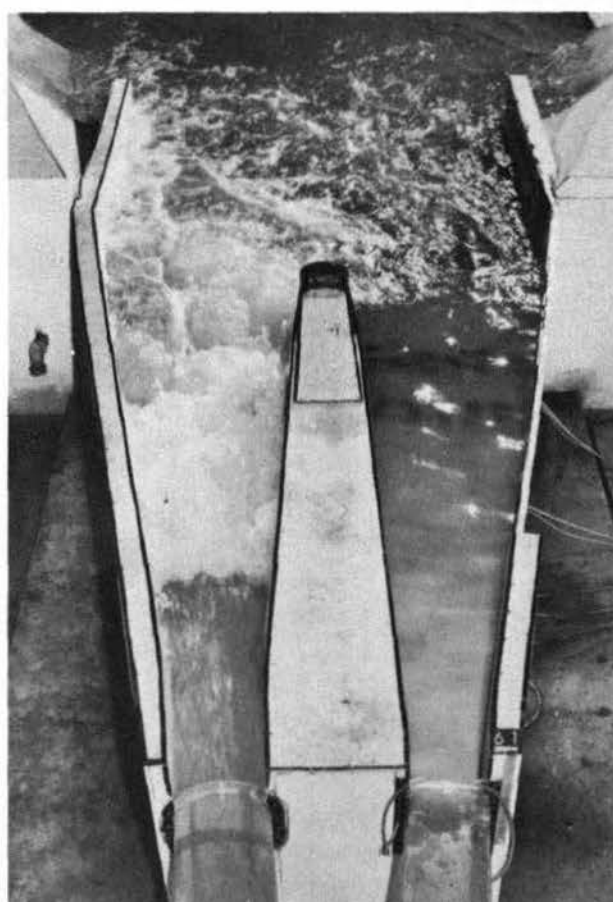
Photograph 17. Flow through left horseshoe-shaped conduit. Test conditions same as photograph 16



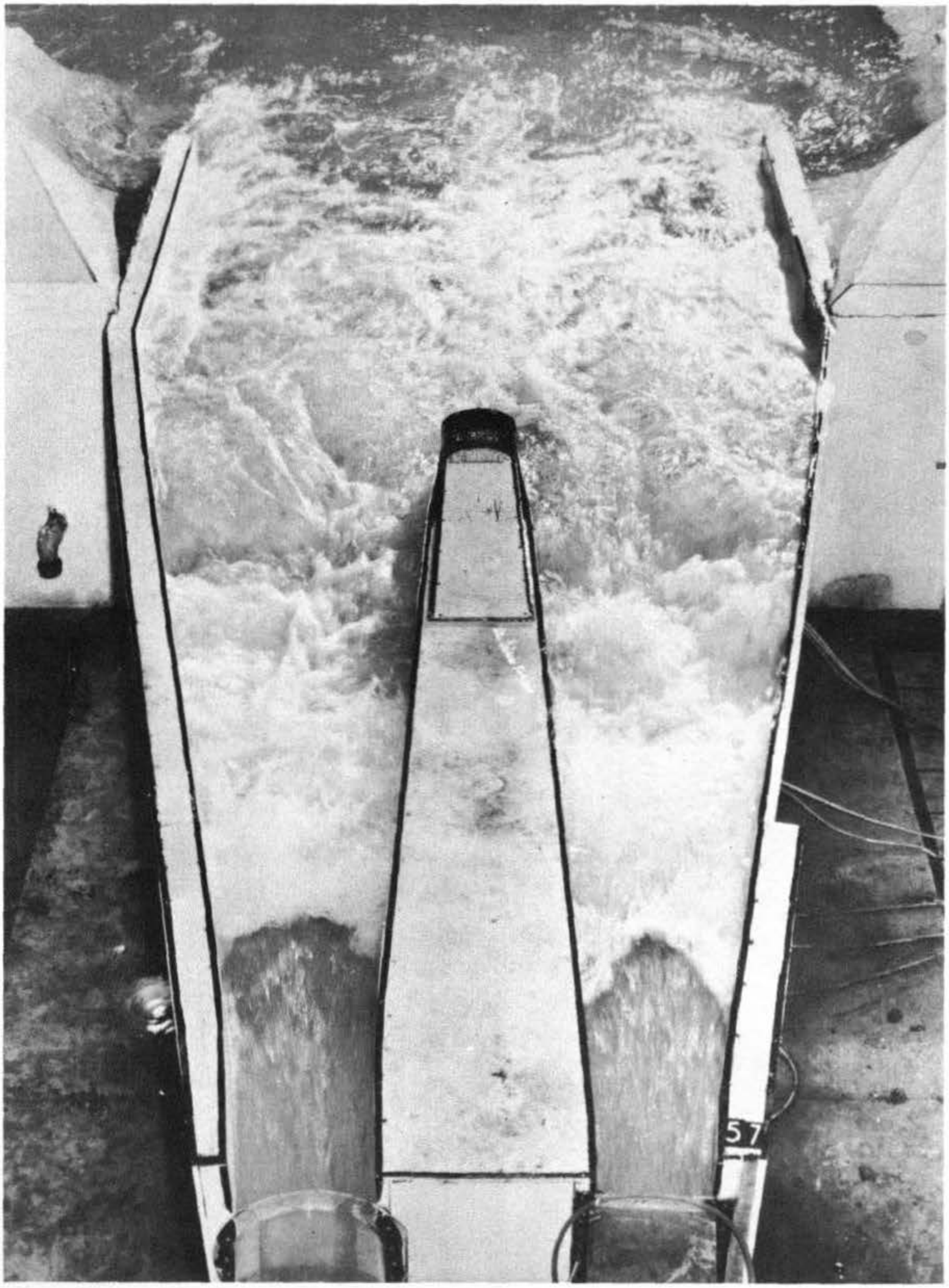
Photograph 18. Flow through both conduits. Stilling basin raised to el 977.0, end sill (sta 7+86) and exit channel at el 995.0. Pier length shortened 50 ft (sta 7+17). Discharge 45,000 cfs, tailwater el 1022.2



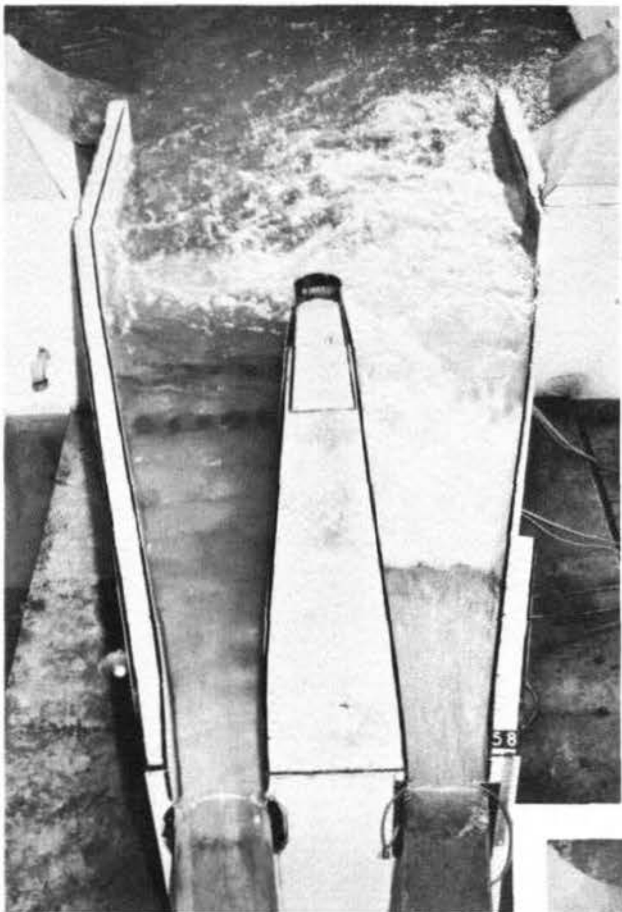
Photograph 19. Right rectangular conduit flow. Stilling basin raised to el 977.0, end sill (sta 7+86) and exit channel at el 995.0. Pier length shortened 50 ft (sta 7+17). Discharge 22,500 cfs, tailwater el 1017.0



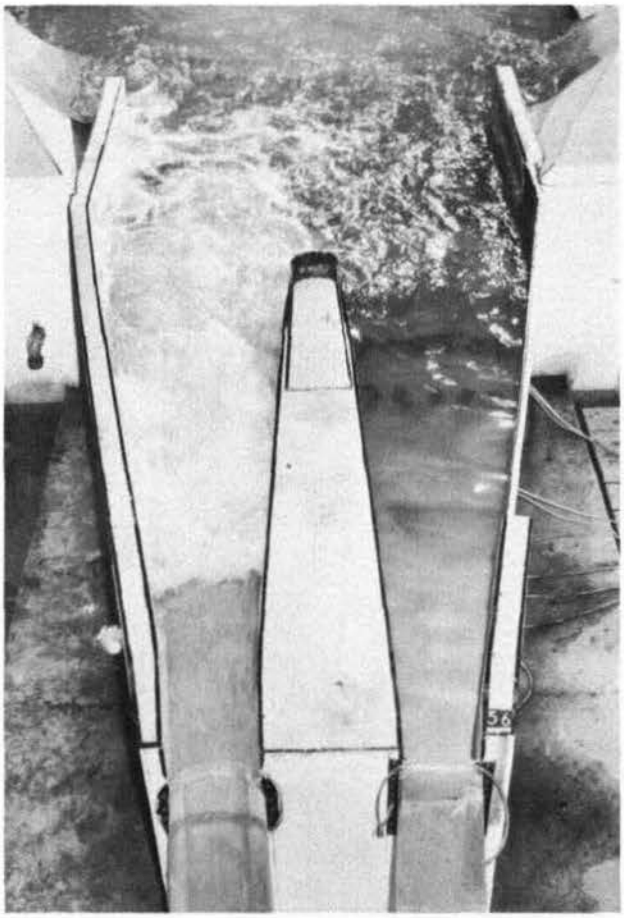
Photograph 20. Left horseshoe-shaped conduit flow. Test conditions same as photograph 19



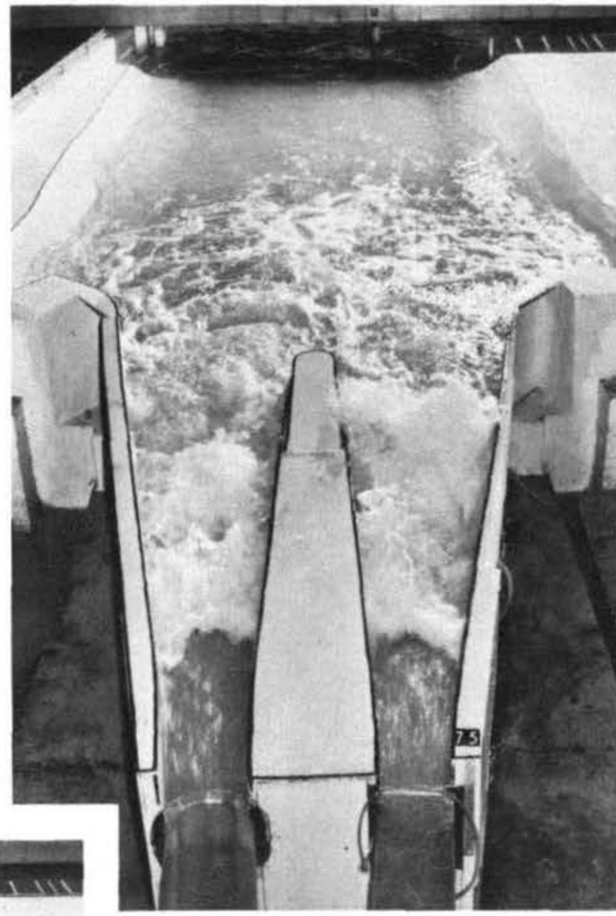

Photograph 21. Flow through both conduits, stilling basin at el 977.0 and basin shortened 30 ft (sta 7+56). End sill (sta 7+56) and exit channel at el 995.0, pier length shortened 50 ft (sta 7+17). Discharge 45,000 cfs, tailwater 1022.2



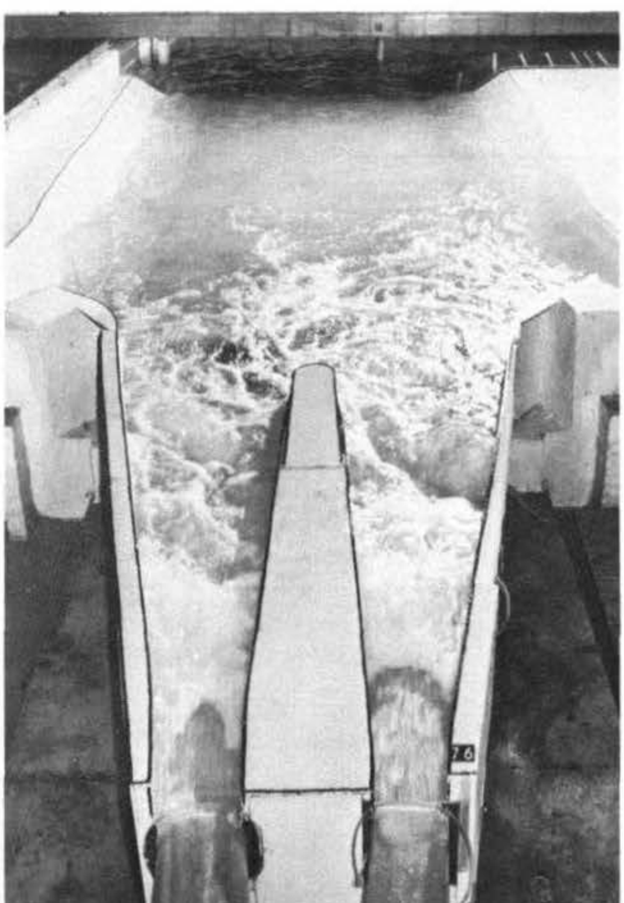
Photograph 22. Right rectangular conduit flow. Stilling basin at el 977.0 and basin shortened 30 ft (sta 7+56). End sill (sta 7+56) and exit channel at el 995.0, pier length shortened 50 ft (sta 7+17). Discharge 22,500 cfs, tailwater el 1017.0



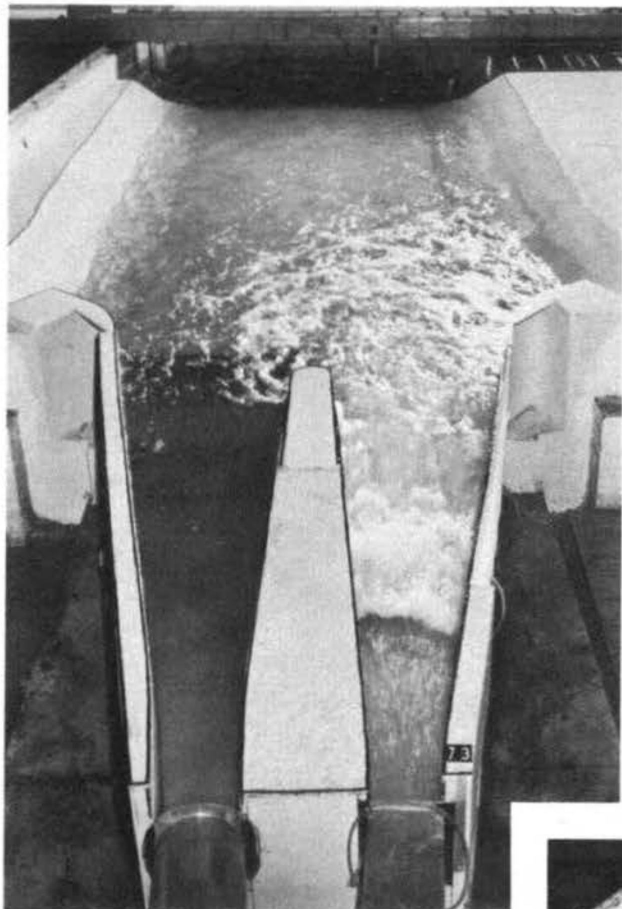
Photograph 23. Left horseshoe-shaped conduit flow with same test conditions as photograph 22



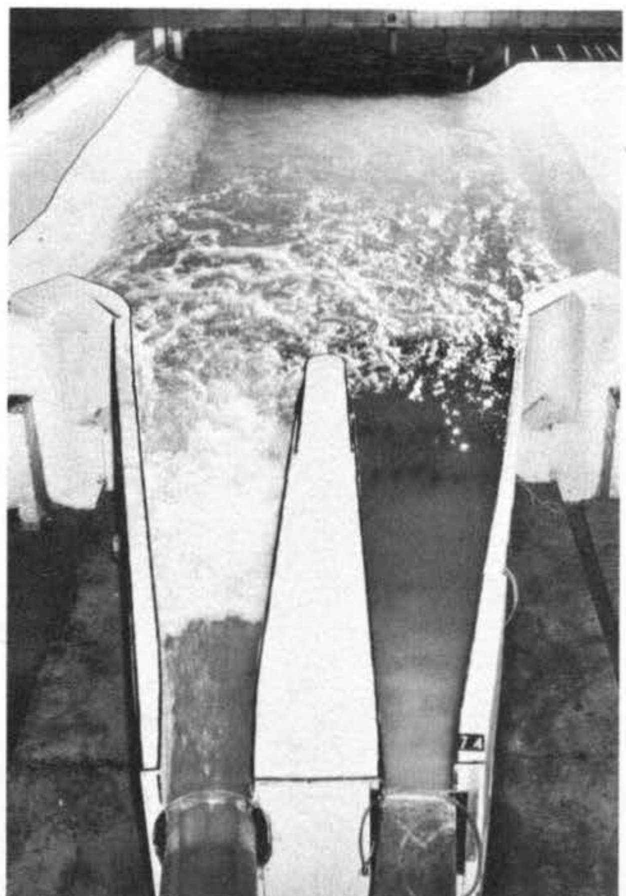
Photograph 24. Action in recommended-design stilling basin and flow in exit area with right rectangular conduit and recommended-design left horseshoe-shaped conduit each discharging 22,500 cfs, tailwater el 1022.2



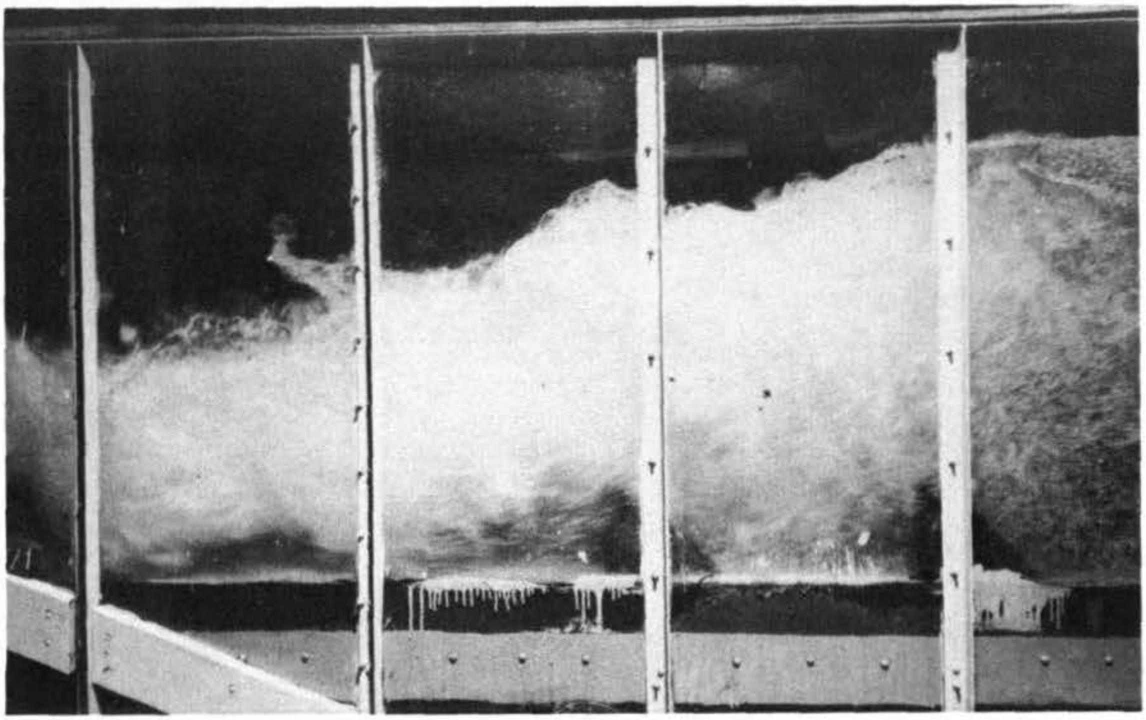
Photograph 25. Same test conditions as photograph 24. Discharge 17,500 cfs from each conduit, tailwater el 1020.2



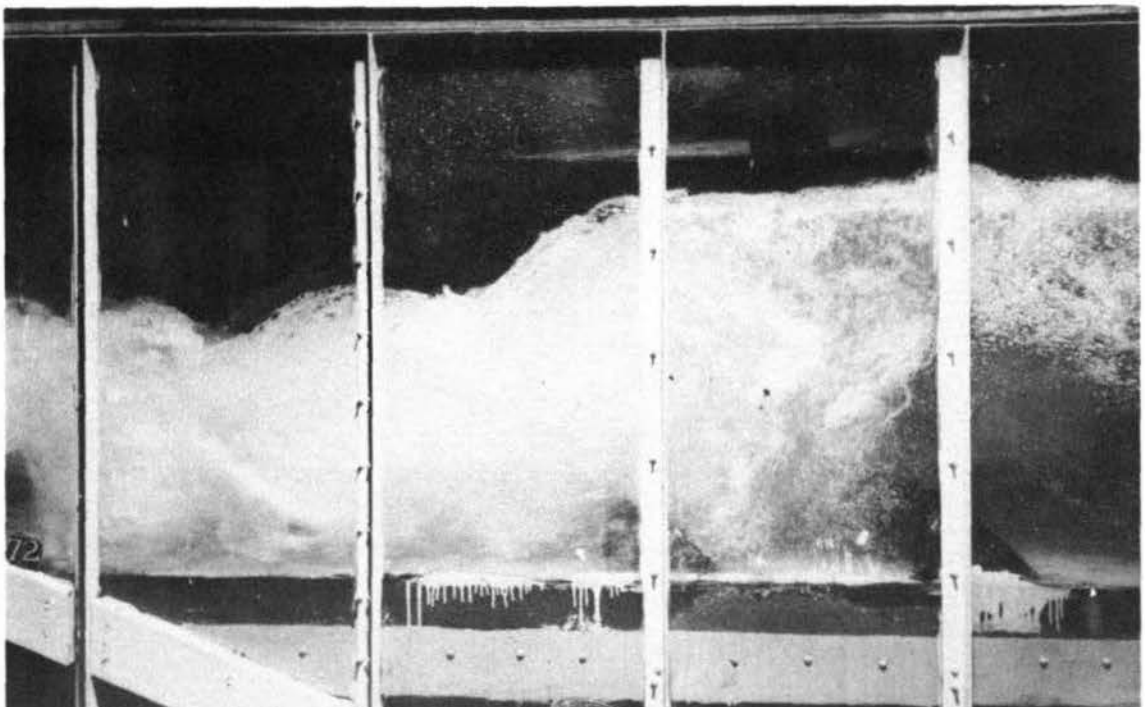
Photograph 26. Action in recommended-design basin and flow in exit area with right rectangular conduit discharging 22,500 cfs, tailwater el 1017.0



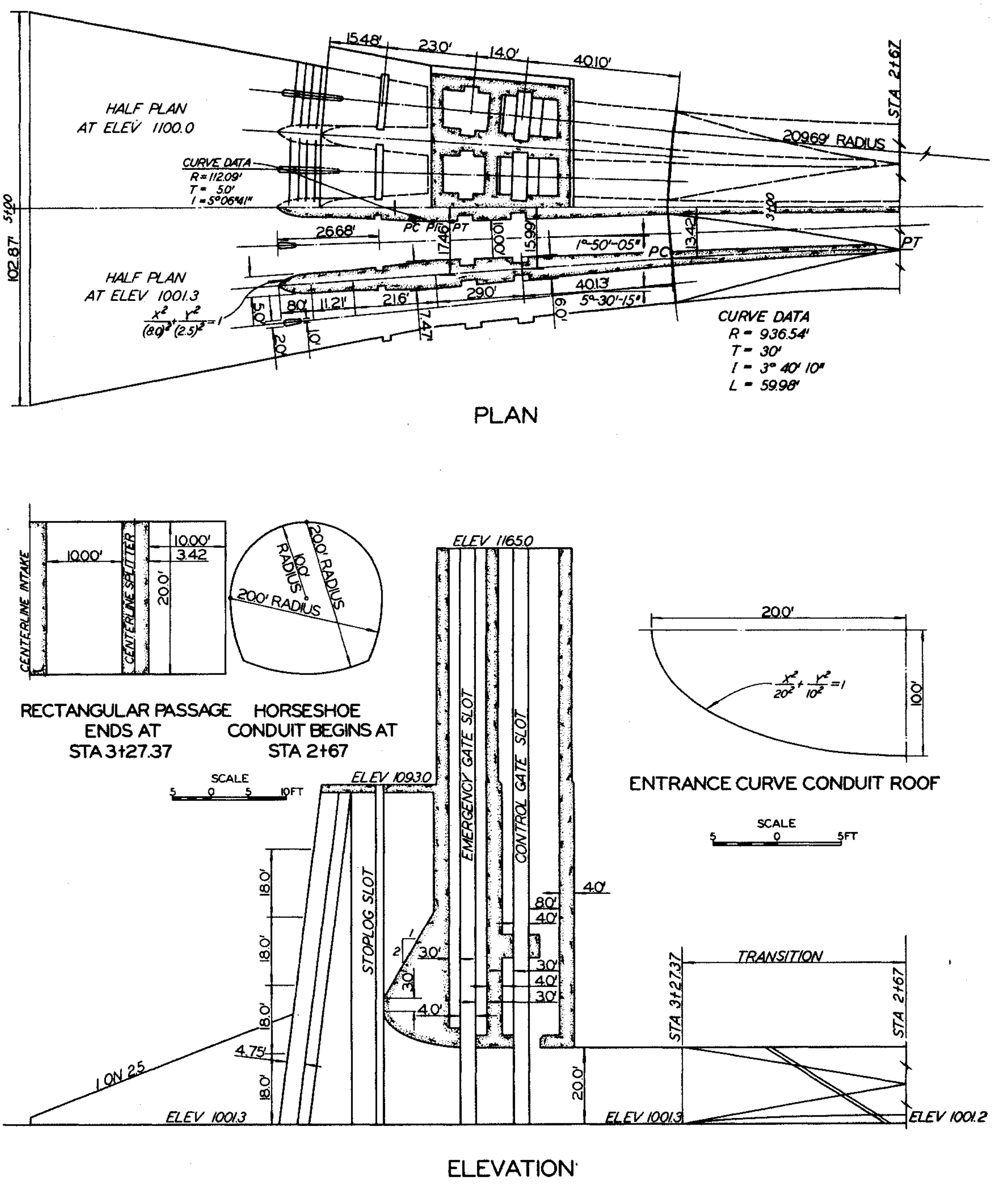
Photograph 27. Action in recommended-design basin and flow in exit area with recommended-design left horseshoe-shaped conduit discharging 22,500 cfs, tailwater el 1017.0



Photograph 28. Action of recommended-design stilling basin with right conduit discharging 22,500 cfs, tailwater el 1017.0



Photograph 29. Action of recommended-design stilling basin with right conduit discharging 17,500 cfs, tailwater el 1015.0

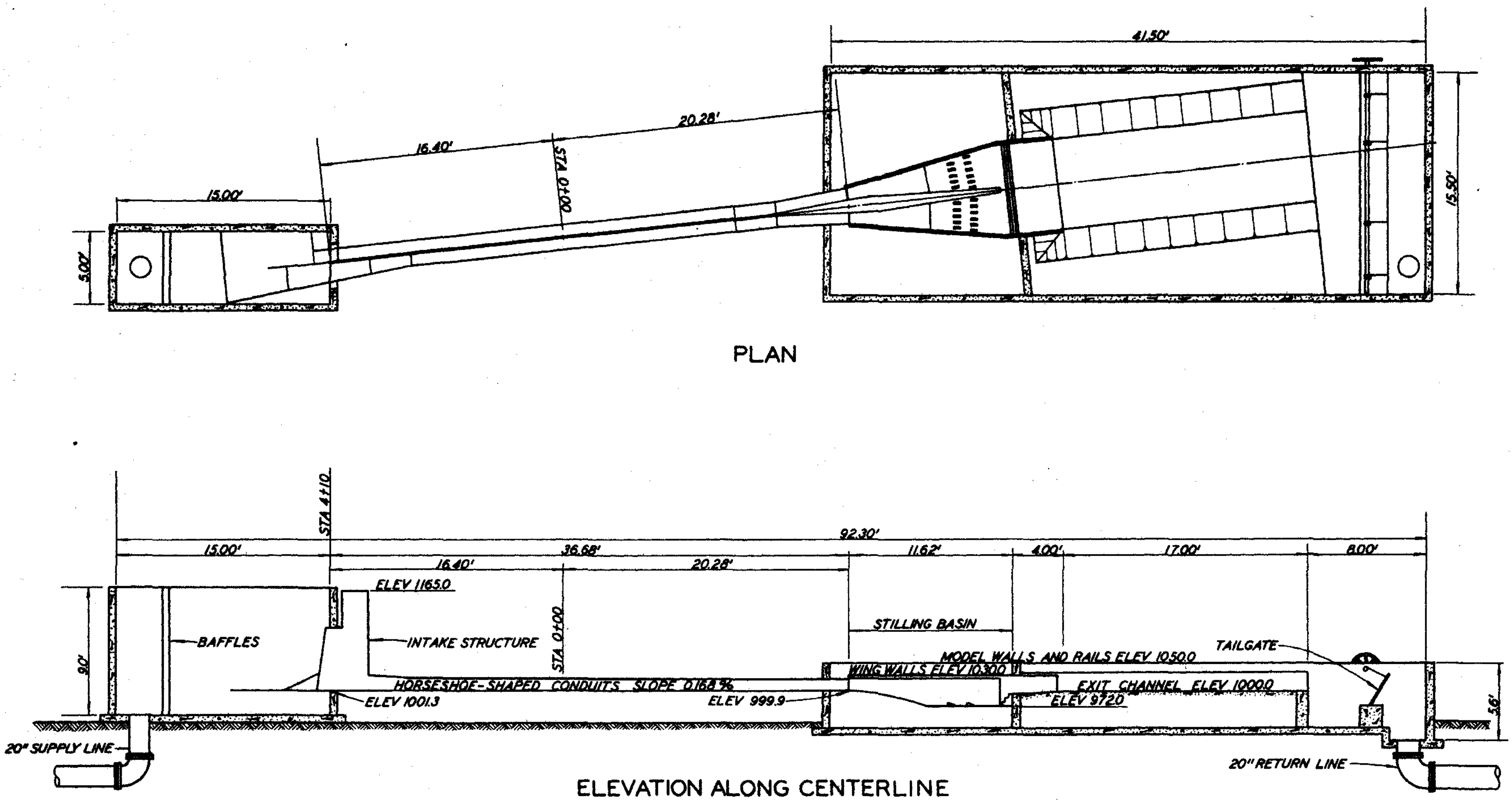



NOTE: ELEVATIONS ARE IN FEET MEAN SEA LEVEL.
ALL VALUES ARE IN PROTOTYPE UNITS.

## INTAKE STRUCTURE AND UPSTREAM TRANSITION

SCALE

25 0 25 50 75FT



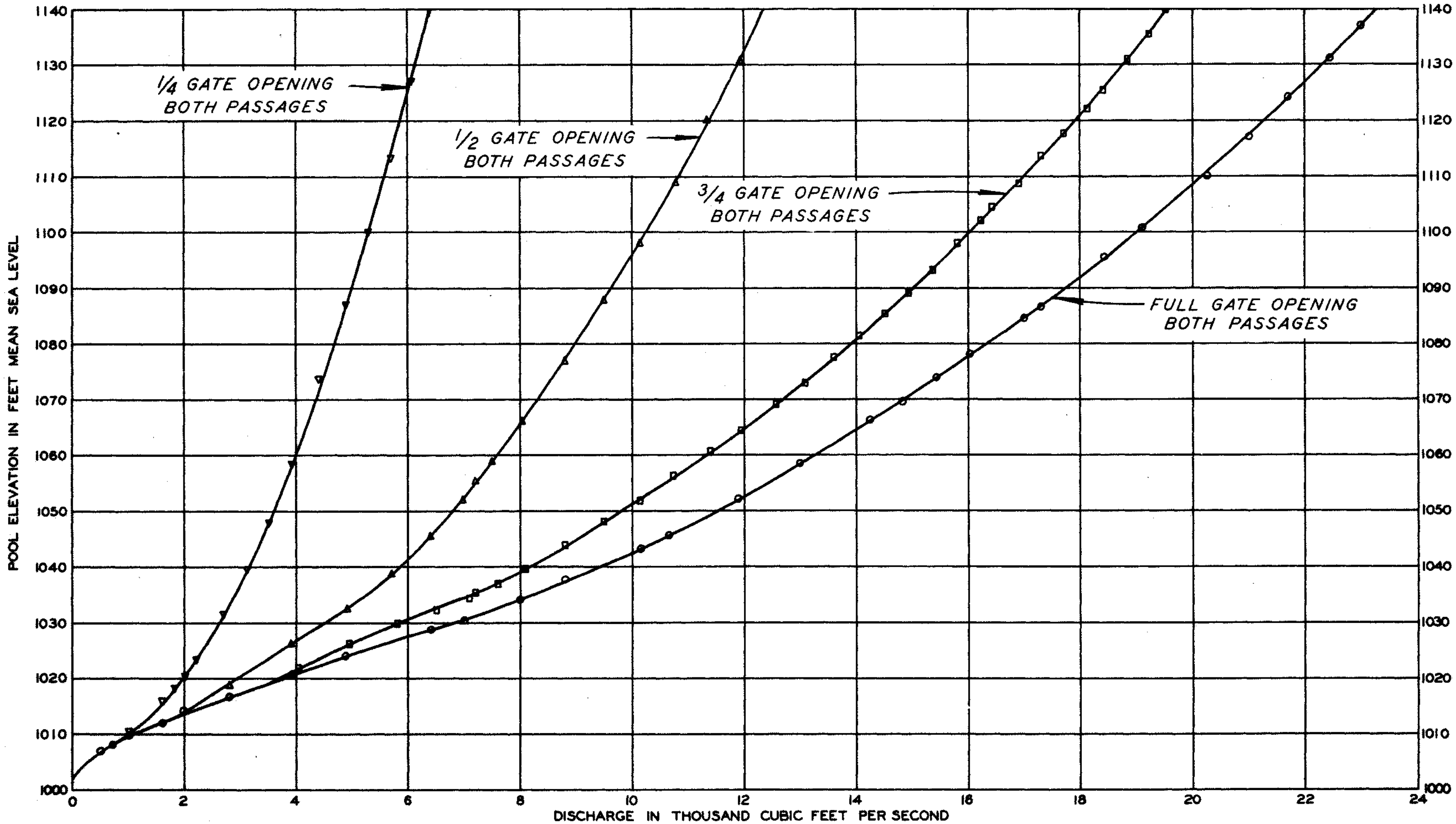

NOTE: ELEVATIONS ARE IN FEET MEAN SEA LEVEL.
ALL DIMENSION ARE IN MODEL UNITS.

# MODEL LAYOUT

SCALES

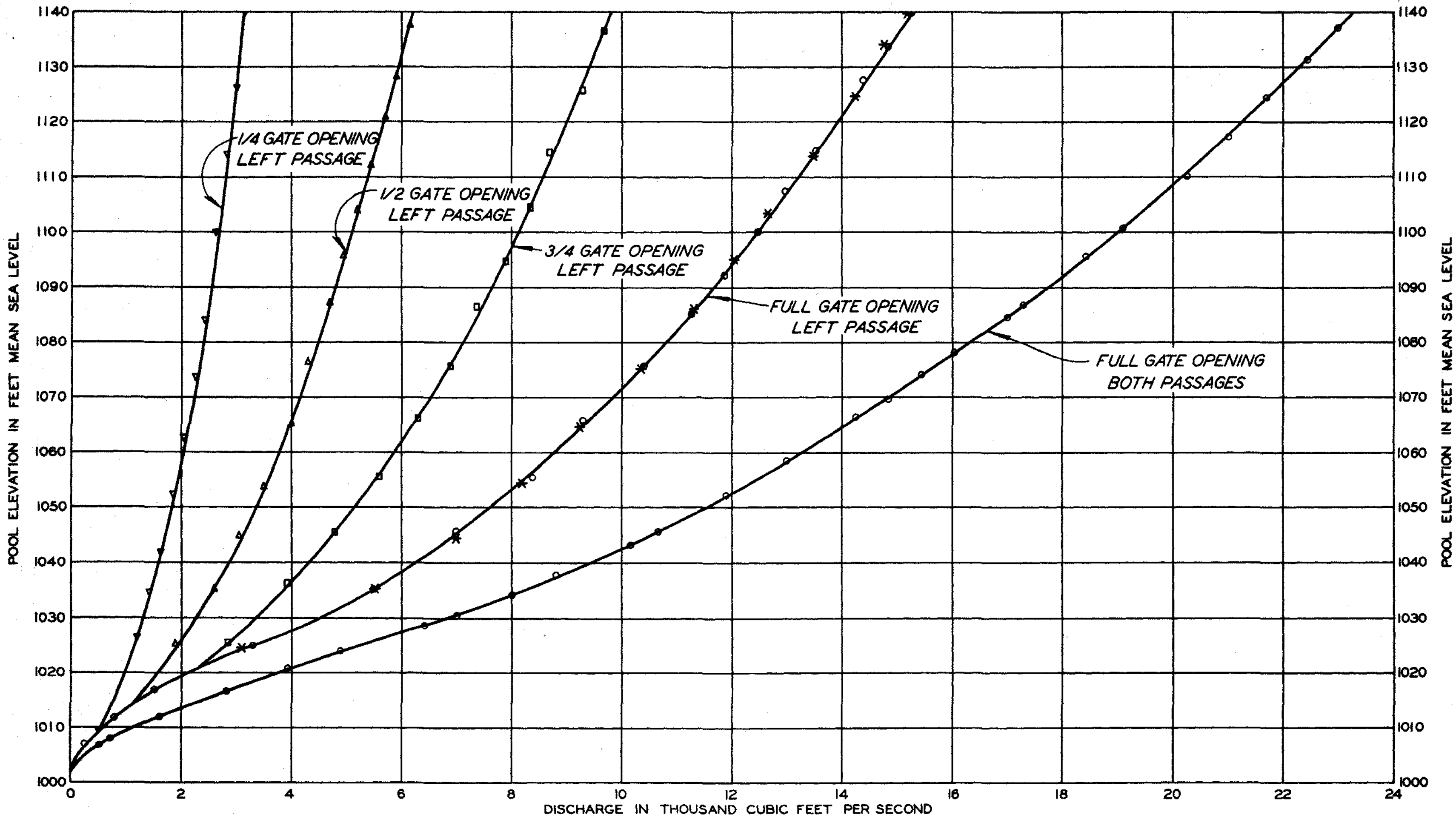
PROTOTYPE 100 0 100 200 300 FT

MODEL 4 0 4 8 12 FT



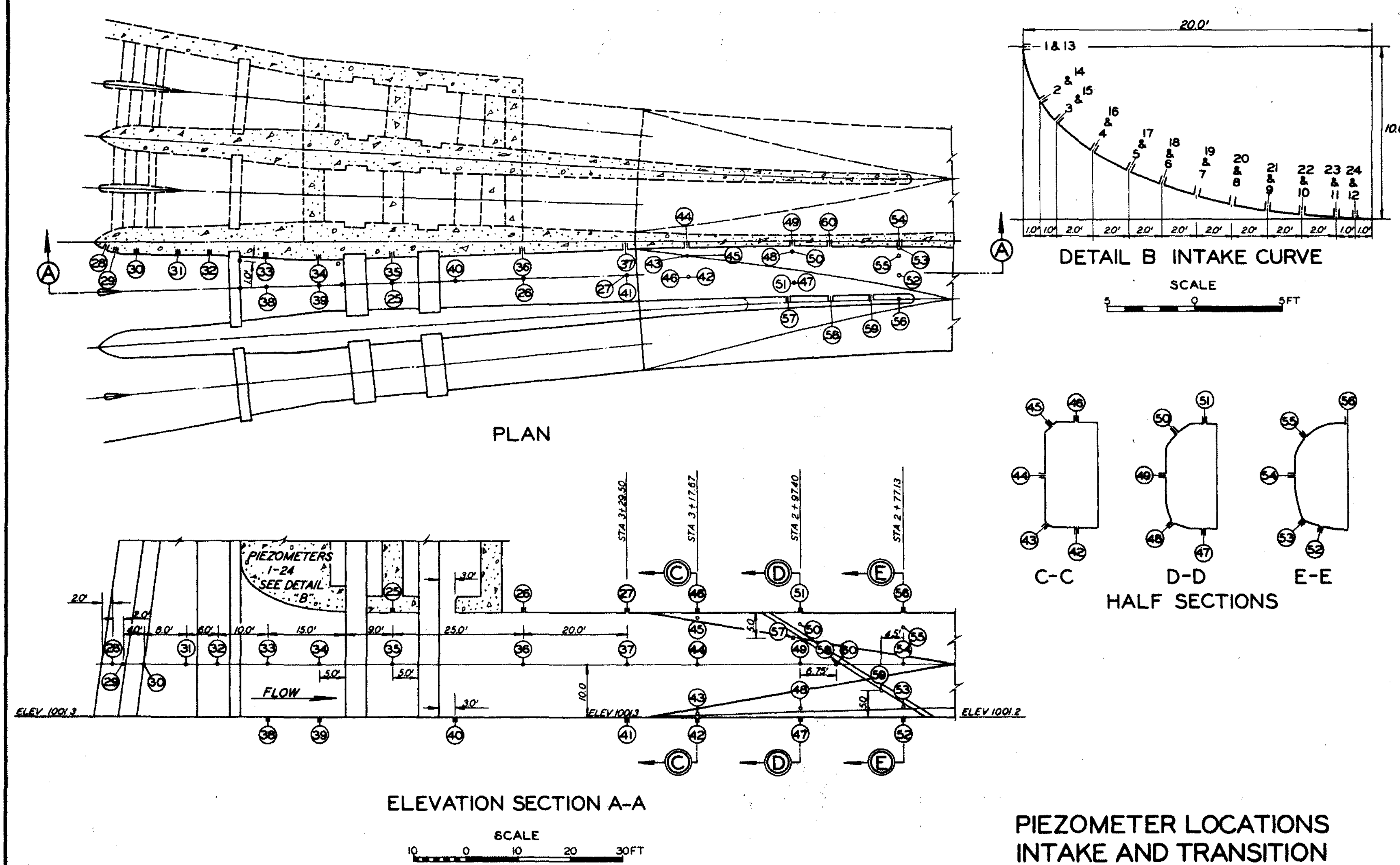

OUTLET WORKS RATING CURVE
RIGHT CONDUIT ORIGINAL DESIGN

PLATE 4

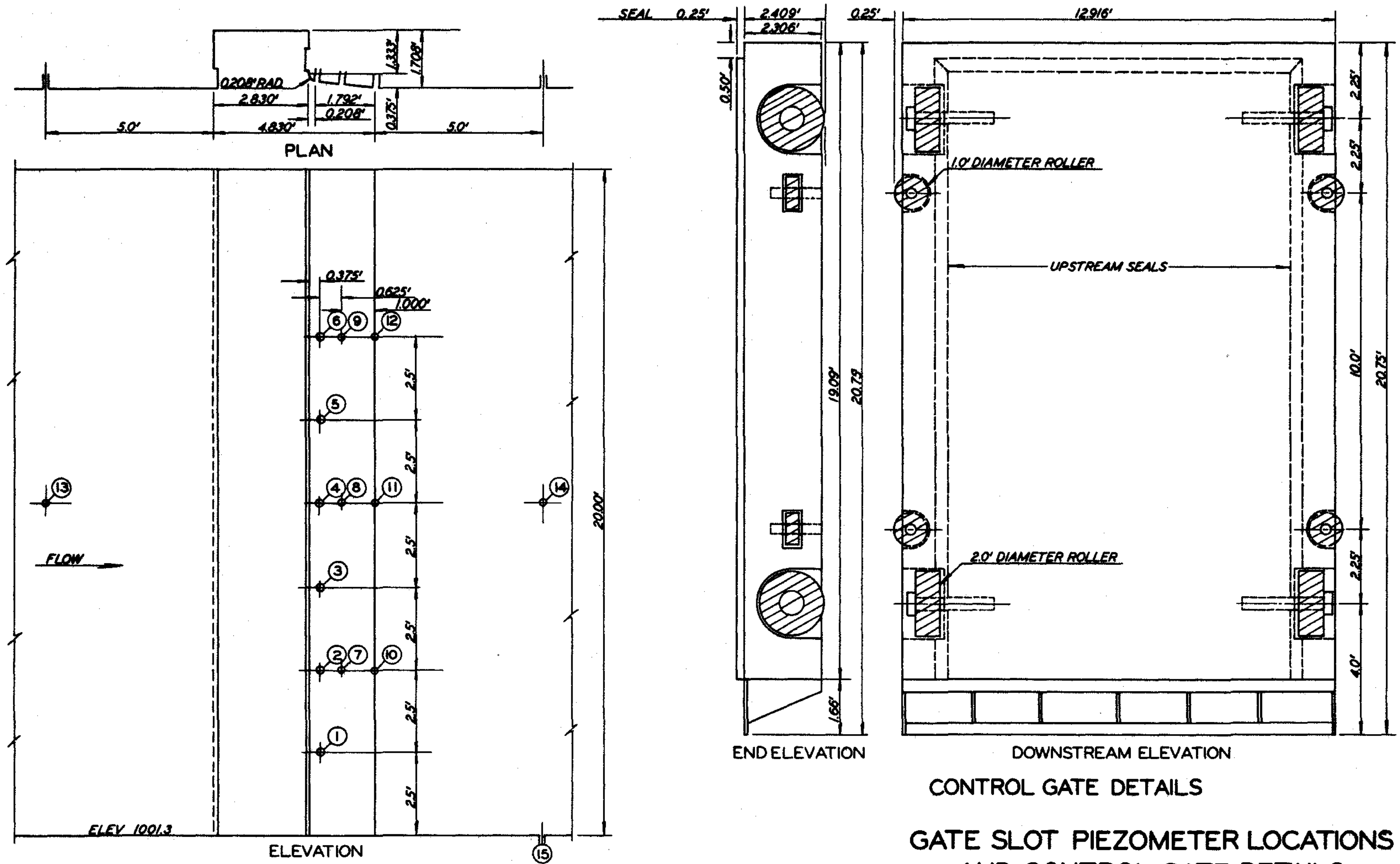



NOTE: * INDICATES CHECK RUN FOR FULL GATE OPENING AND FLOW THROUGH RIGHT PASSAGE OF RIGHT CONDUIT.

RATING CURVES
FULL AND PARTIAL GATE OPENINGS
RIGHT CONDUIT ORIGINAL DESIGN




PIEZOMETER LOCATIONS
INTAKE AND TRANSITION
ORIGINAL DESIGN



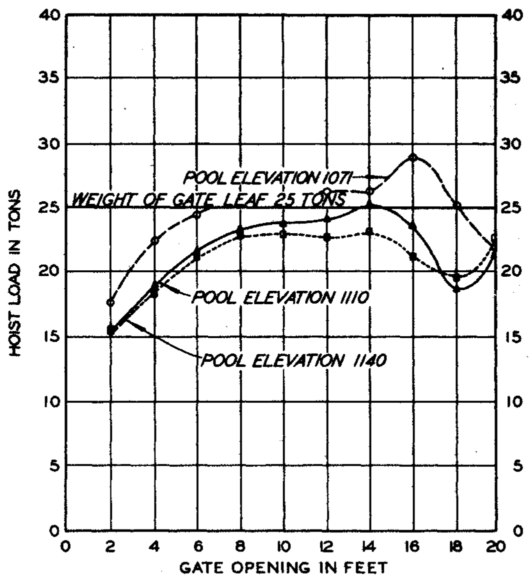

GATE SLOT DETAILS

CONTROL GATE DETAILS

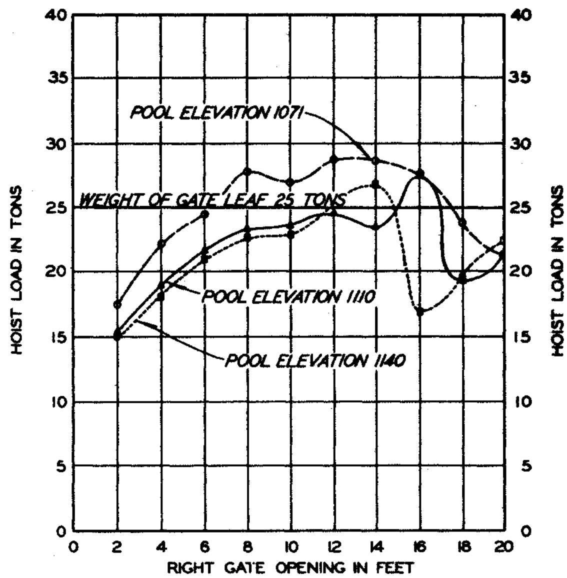
NOTE: ALL GATE SLOT PIEZOMETERS ARE LOCATED ON THE RIGHT WALL OF THE RIGHT PASSAGE OF THE RIGHT CONDUIT.
ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL.

GATE SLOT PIEZOMETER LOCATIONS AND CONTROL GATE DETAILS
ORIGINAL DESIGN

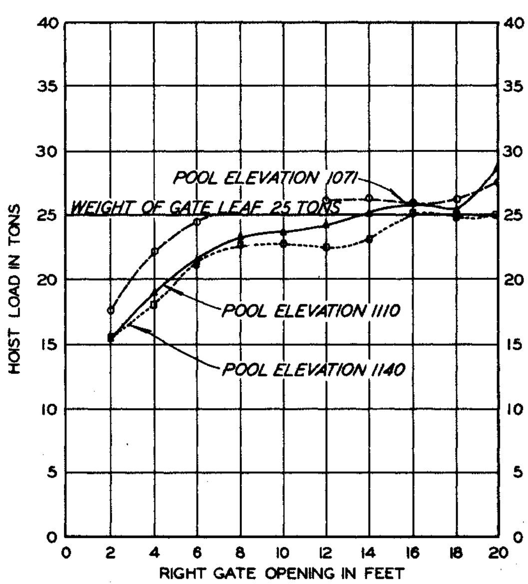
SCALE
20 0 20 40 60 FT




BOTH GATES OPEN EQUAL AMOUNTS



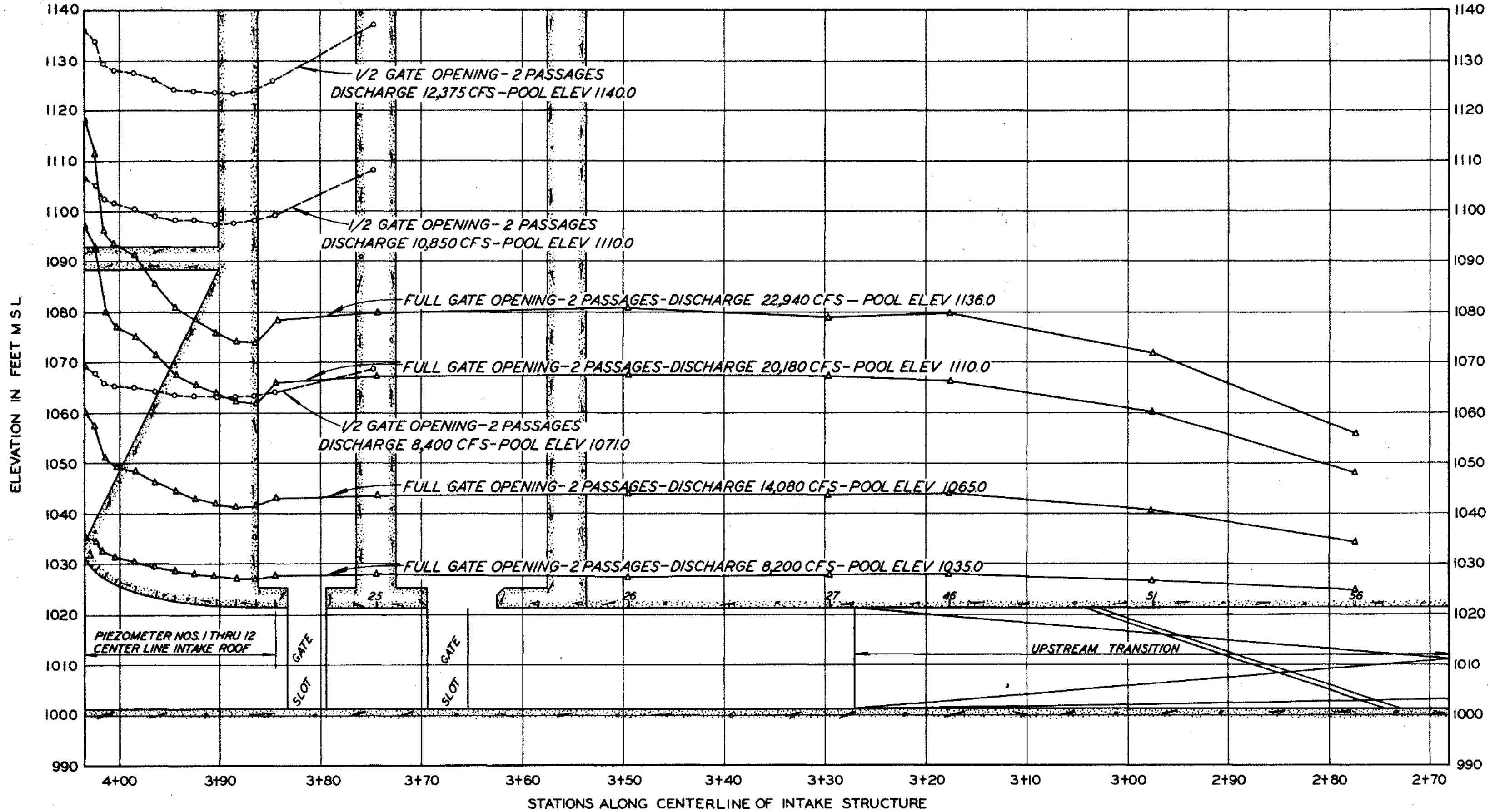

LEFT GATE OPEN FULL
RIGHT GATE OPEN AS INDICATED




LEFT GATE CLOSED
RIGHT GATE OPEN AS INDICATED

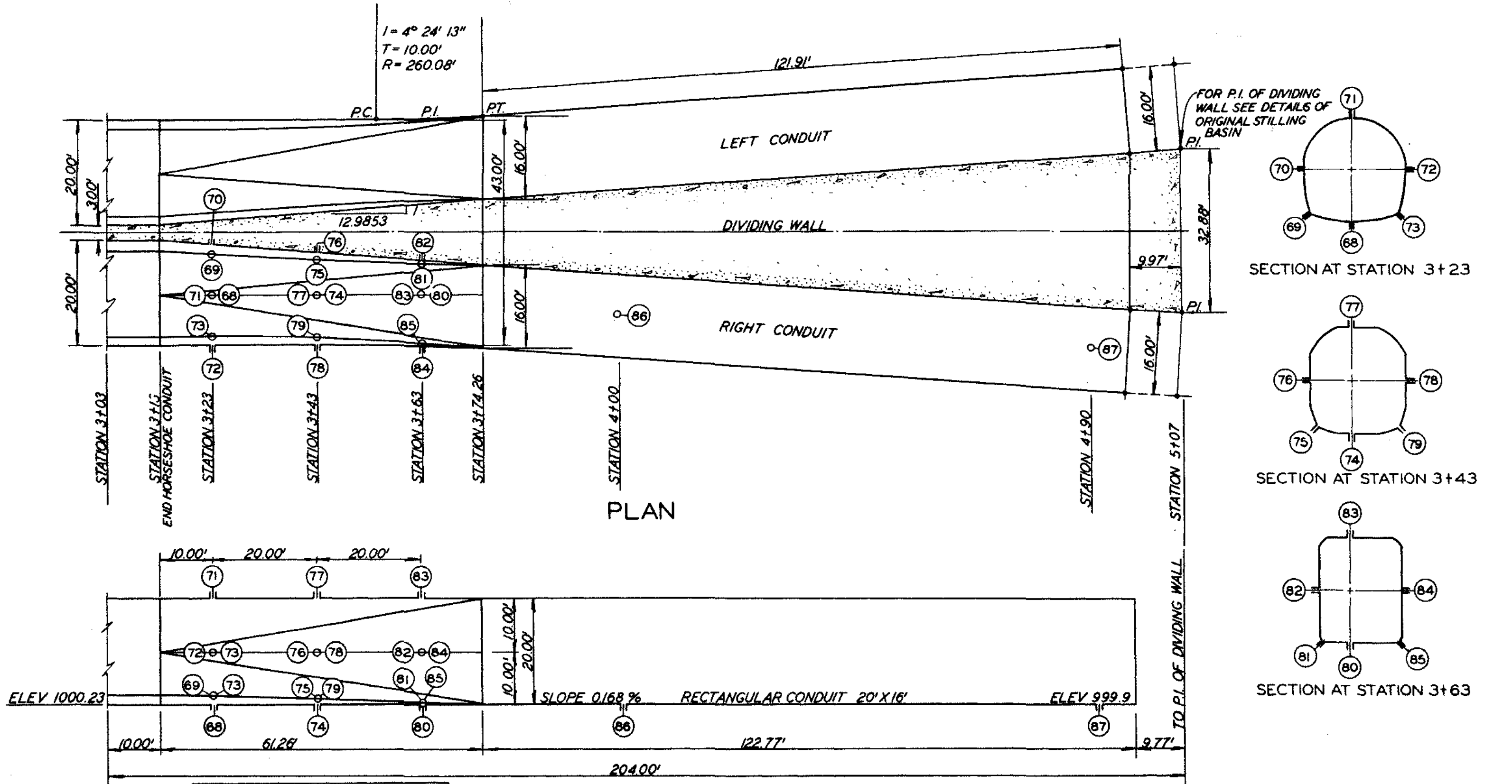
NOTE: ALL FORCE MEASUREMENTS WERE MADE ON THE RIGHT GATE OF THE RIGHT CONDUIT.
ELEVATIONS ARE IN FEET MEAN SEA LEVEL.

## OPERATING FORCES
ORIGINAL DESIGN GATE

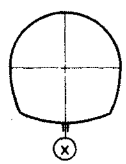



NOTE: PIEZOMETERS 26, 27, 46, 51, AND 56 ARE ABOVE THE WATER SURFACE FOR 2 GATE PASSAGES HALF OPEN.

# PRESSURE GRADIENTS
## INTAKE AND UPSTREAM TRANSITION
### ORIGINAL DESIGN




| PIEZOMETERS ON HORSESHOE CONDUIT SECTION | | |
|---|---|---|
| PIEZOMETER | STATION | ELEVATION |
| 61 | 2+50 | 1001.2 |
| 62 | 2+00 | 1001.1 |
| 63 | 1+00 | 1000.9 |
| 64 | 0+00 | 1000.75 |
| 65 | 1+00 D | 1000.6 |
| 66 | 2+00 D | 1000.4 |
| 67 | 3+00 D | 1000.23 |
| X DENOTES PIEZOMETERS 61 THRU 67 | | |

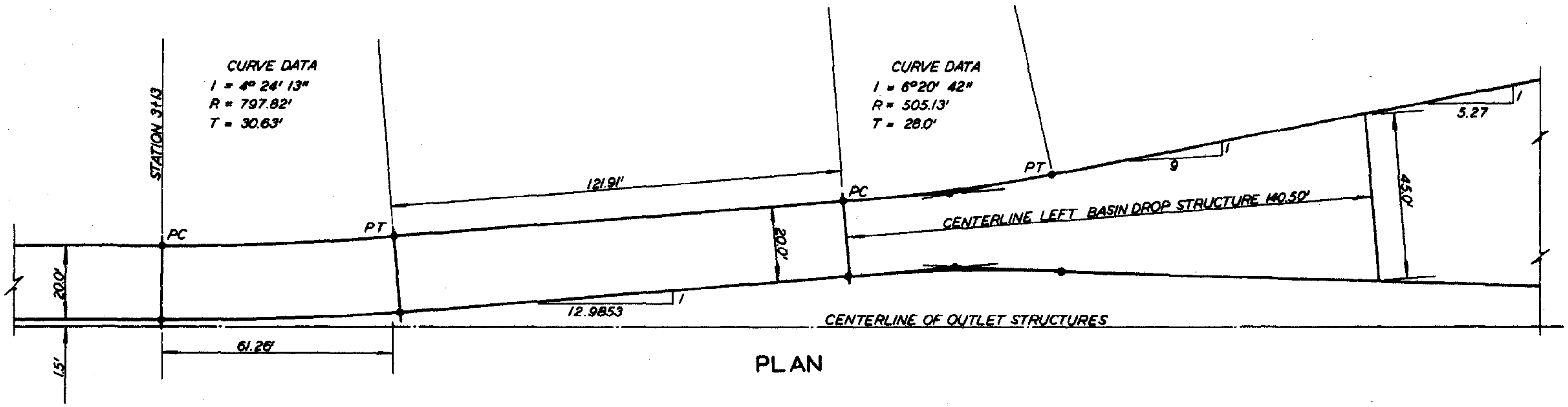


SECTION HORSESHOE CONDUIT

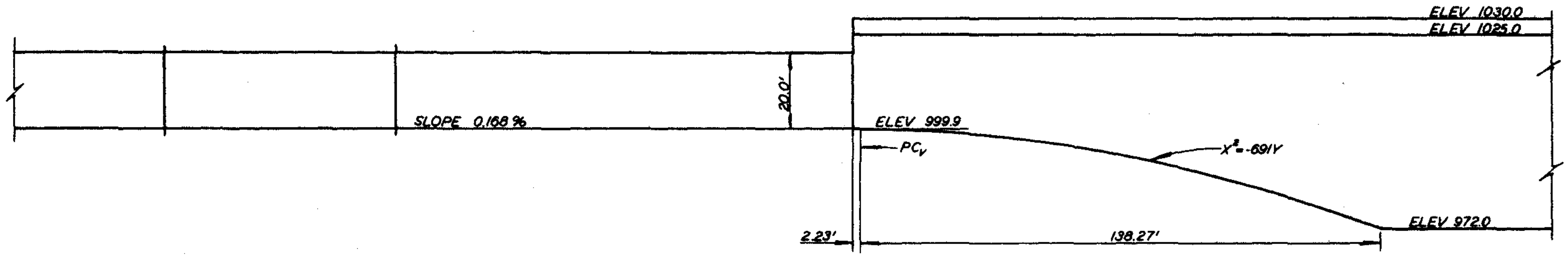
# CONDUIT PIEZOMETER LOCATIONS

## HORSESHOE SECTION - OUTLET TRANSITION AND RECTANGULAR SECTION ORIGINAL DESIGN

PLATE 10




PLAN



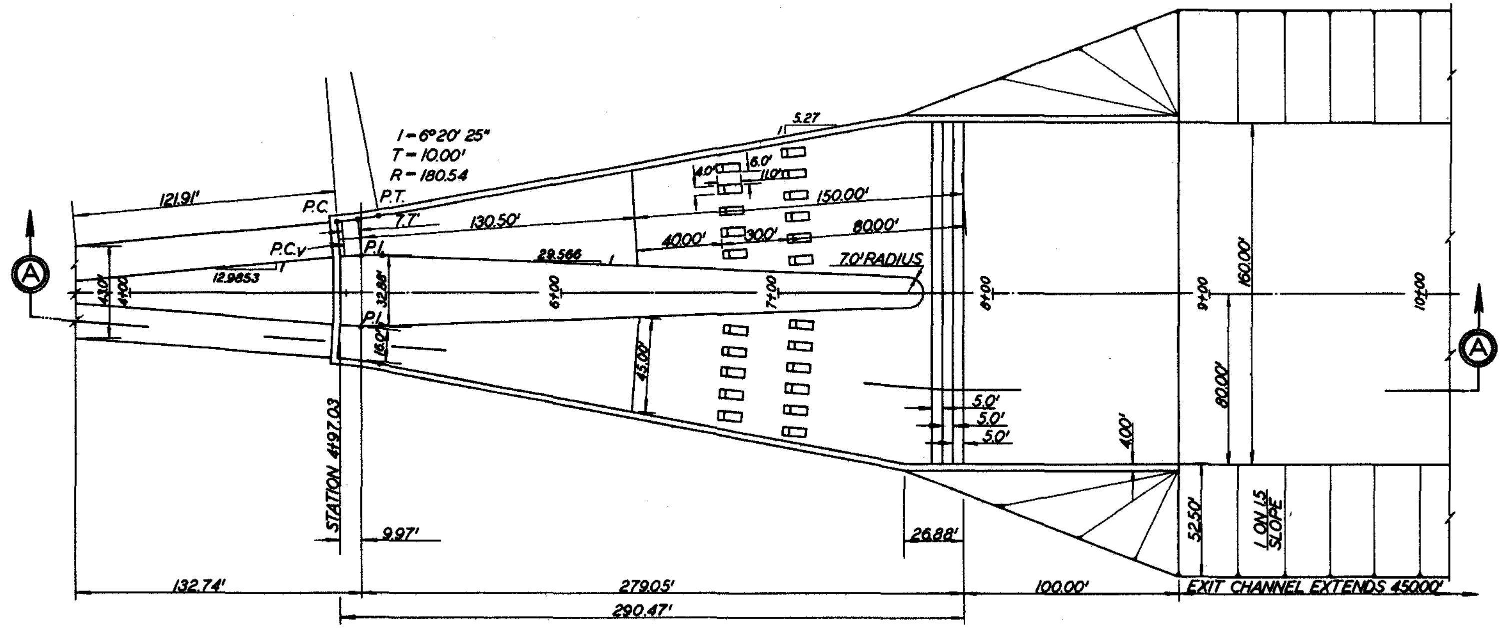

ELEVATION


SECTION
HORSESHOE CONDUIT

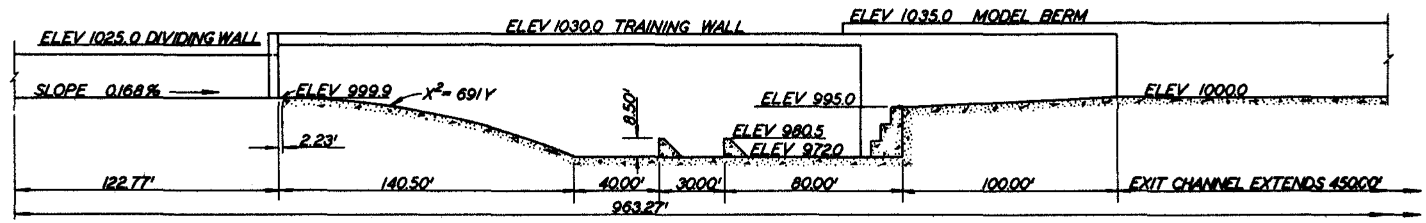
NOTE: STATION 0+00 IS THE AXIS OF DAM.
ELEVATIONS ARE IN FEET MEAN SEA LEVEL.
ALL VALUES ARE IN PROTOTYPE UNITS.

INSTALLATION LEFT HORSESHOE-SHAPED CONDUIT
ORIGINAL DESIGN STILLING BASIN

SCALE
25 0 25 50 75 100FT




PLAN



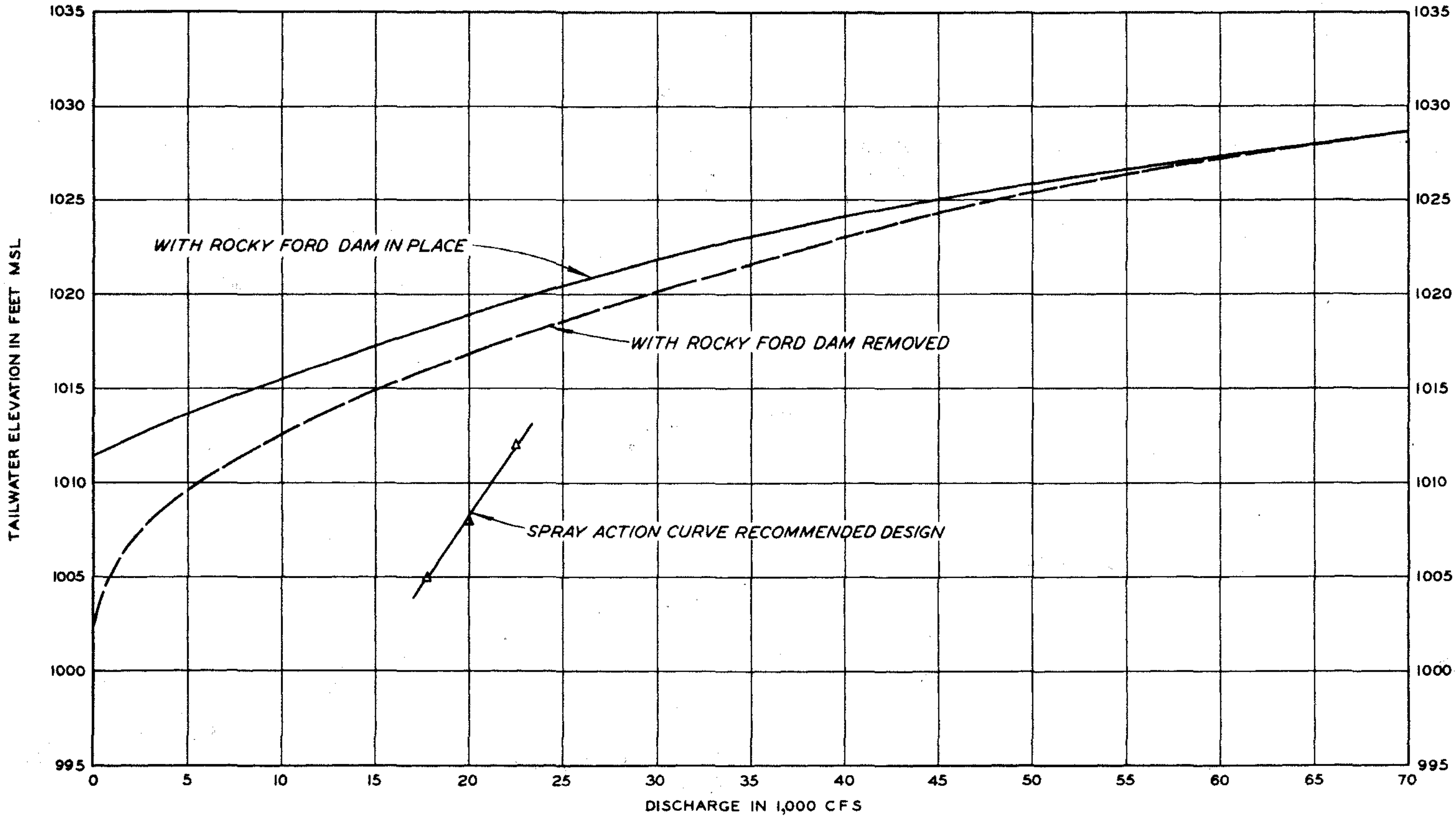

SECTIONAL ELEVATION A-A

NOTE: ELEVATIONS ARE IN FEET MEAN SEA LEVEL.
ALL VALUES ARE IN PROTOTYPE UNITS.

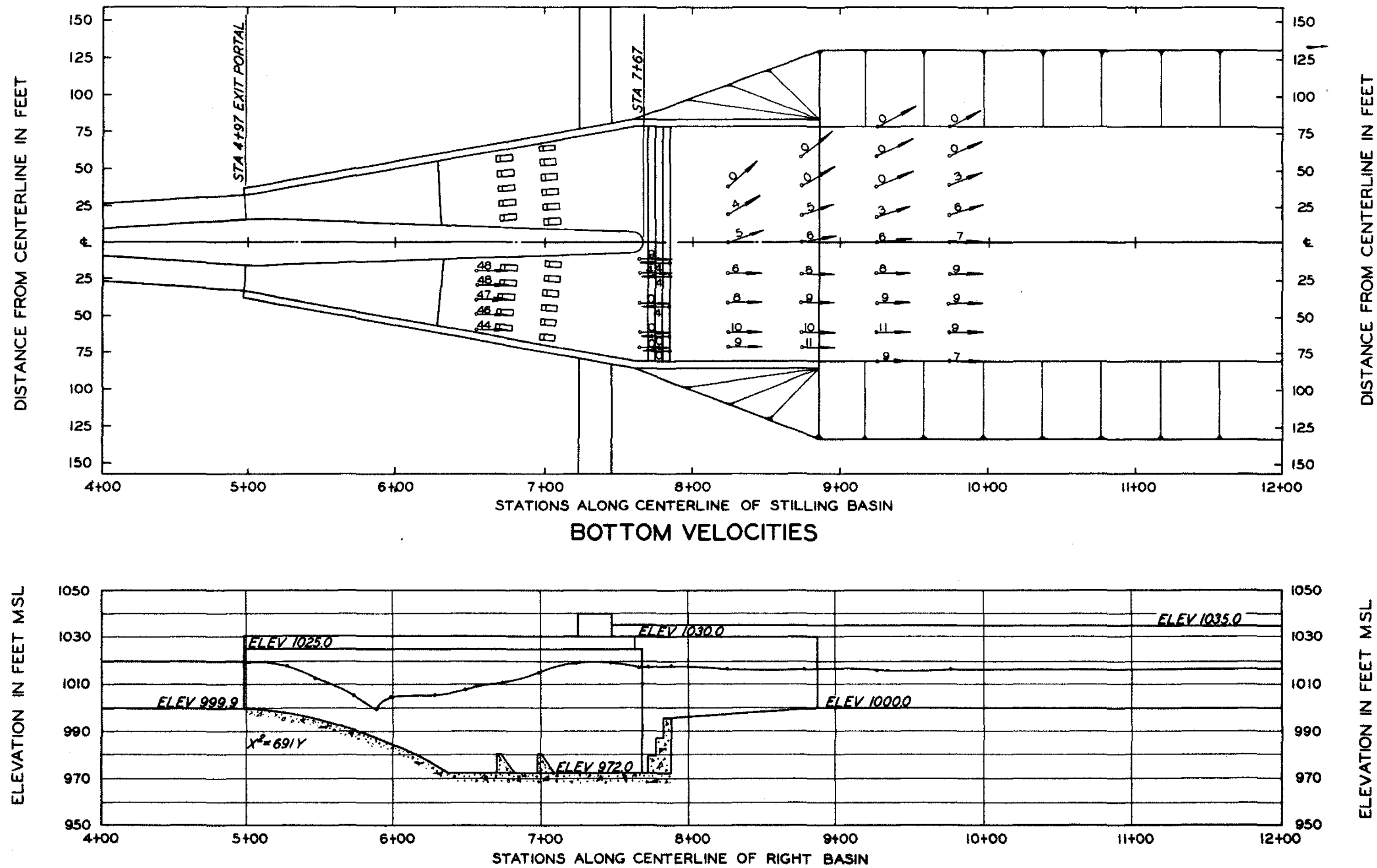
## STILLING BASIN DETAILS
ORIGINAL DESIGN

SCALE
50 0 50 100 FT

PLATE 11




TAILWATER RATING CURVE



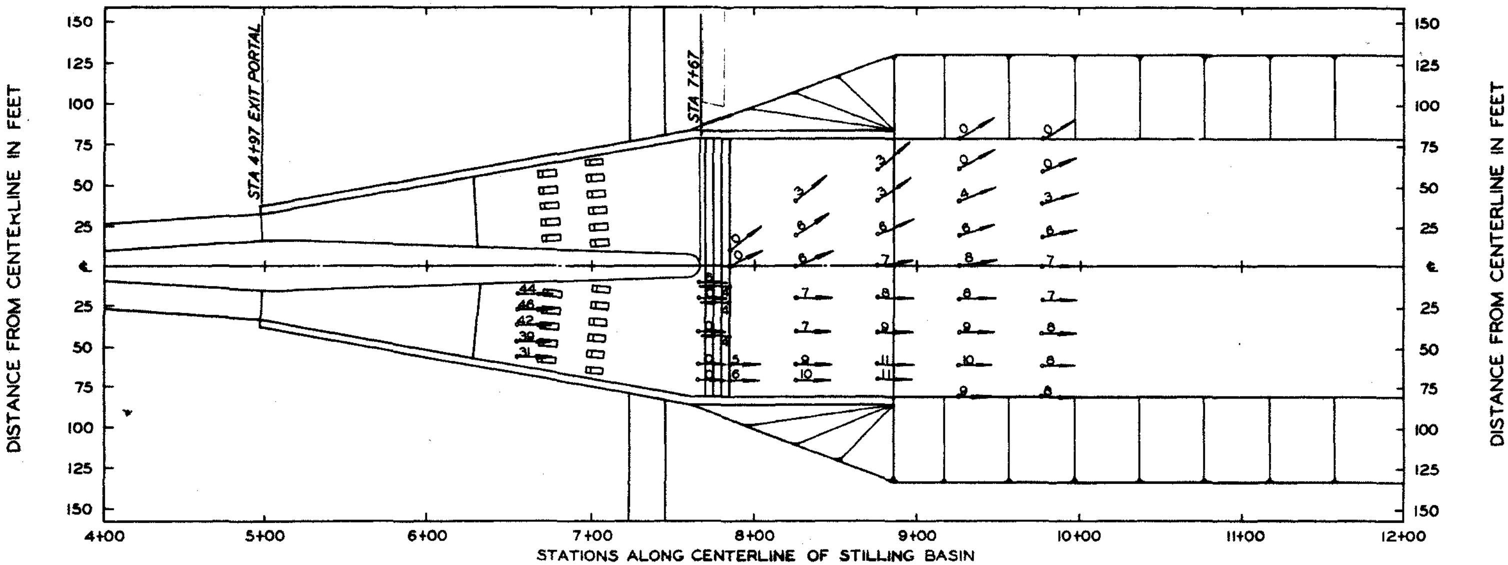

NOTE: STATION 0+00 IS THE AXIS OF DAM.
EXIT CHANNEL MOLDED IN CEMENT MORTAR.
VELOCITY MEASUREMENTS TAKEN 0.5 FT OFF BOTTOM. ZERO VELOCITY INDICATES SOME MOVEMENT IN DIRECTION SHOWN.
VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

# BOTTOM VELOCITIES AND WATER-SURFACE PROFILE

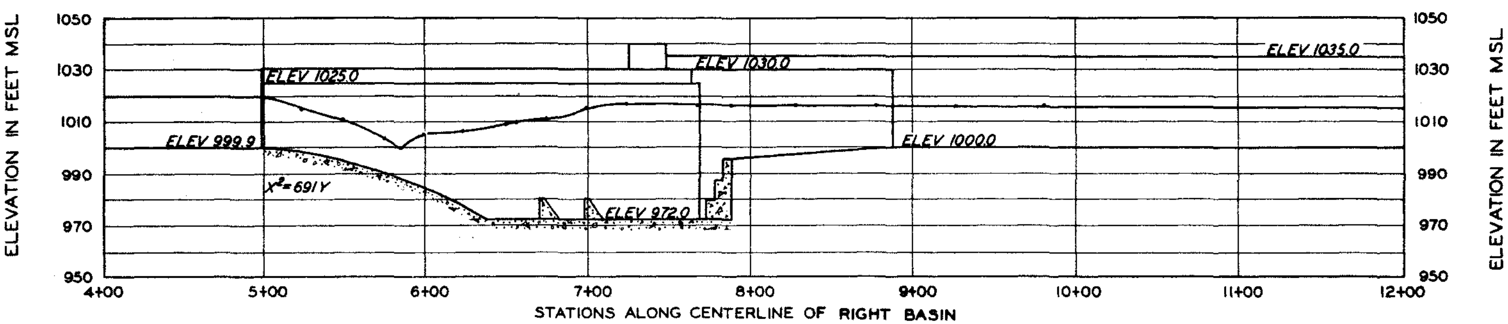
## ORIGINAL DESIGN

DISCHARGE 22,500 CFS TAILWATER ELEVATION 1017.0

PLATE 14




**BOTTOM VELOCITIES**



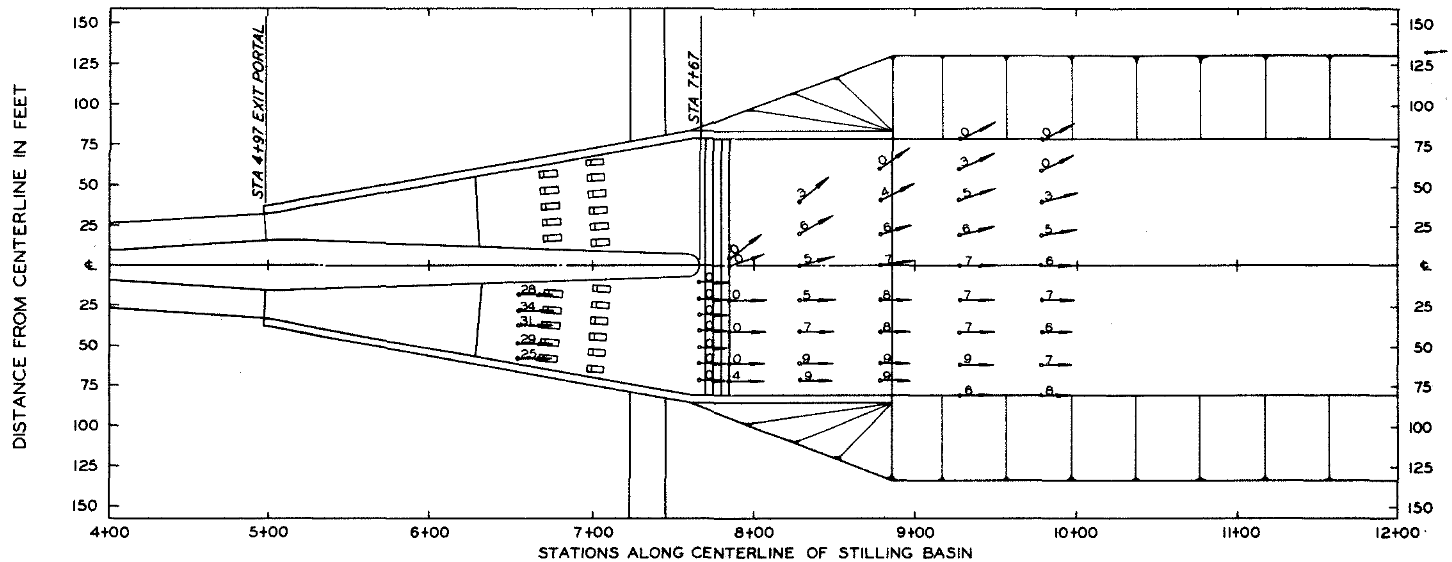

**WATER-SURFACE PROFILE**

NOTE: STATION 0+00 IS THE AXIS OF DAM.
EXIT CHANNEL MOLDED IN CEMENT MORTAR.
VELOCITY MEASUREMENTS TAKEN 0.5 FT OFF BOTTOM. ZERO VELOCITY INDICATES SOME MOVEMENT IN DIRECTION SHOWN.
VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

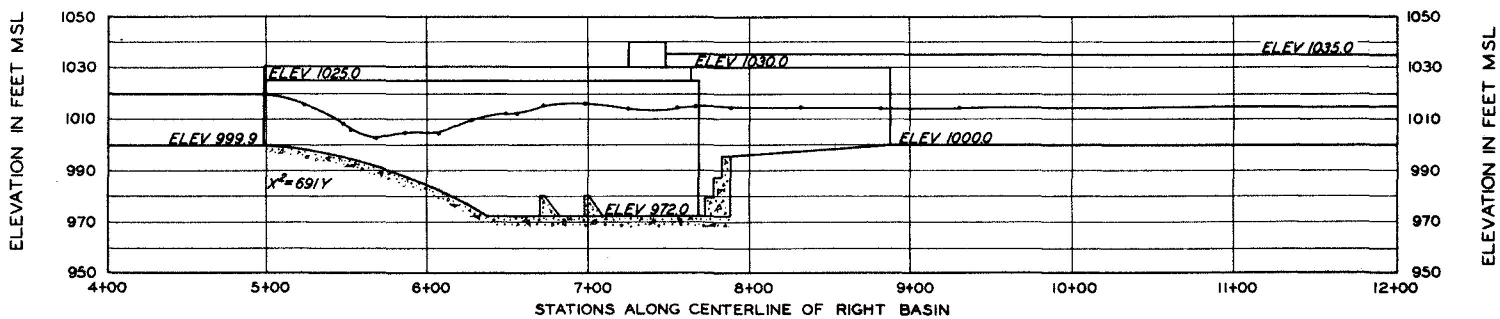
# BOTTOM VELOCITIES AND WATER-SURFACE PROFILE

## ORIGINAL DESIGN

DISCHARGE 20,000 CFS TAILWATER ELEVATION 1016.0




## BOTTOM VELOCITIES



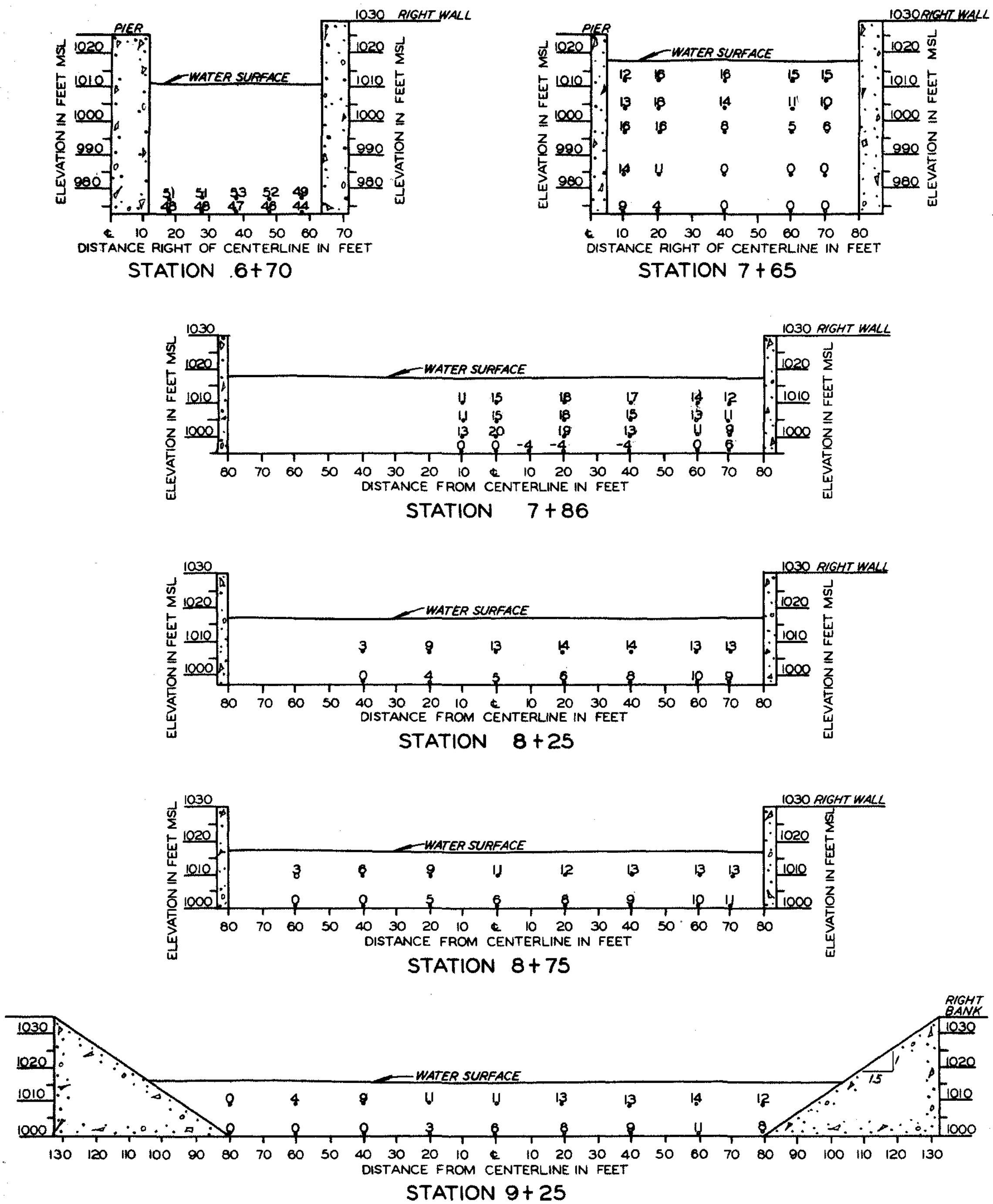

## WATER-SURFACE PROFILE

NOTE: STATION 0+00 IS THE AXIS OF DAM.
EXIT CHANNEL MOLDED IN CEMENT MORTAR.
VELOCITY MEASUREMENTS TAKEN 0.5 FT OFF BOTTOM. ZERO VELOCITY INDICATES SOME MOVEMENT IN DIRECTION SHOWN.
VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

# BOTTOM VELOCITIES AND WATER-SURFACE PROFILE

## ORIGINAL DESIGN

DISCHARGE 15,000 CFS TAILWATER ELEVATION 1014.5




NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

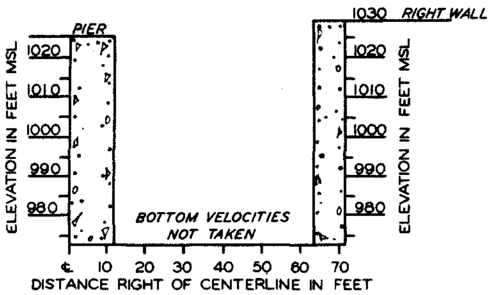
BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR.

## VELOCITIES

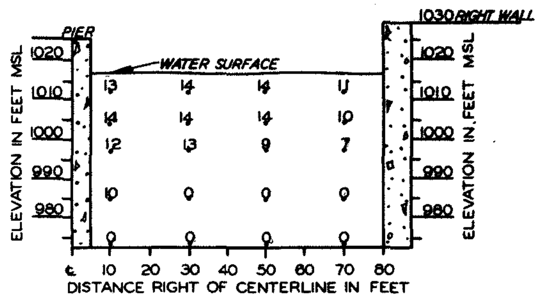
ORIGINAL DESIGN

DISCHARGE 22,500 CFS

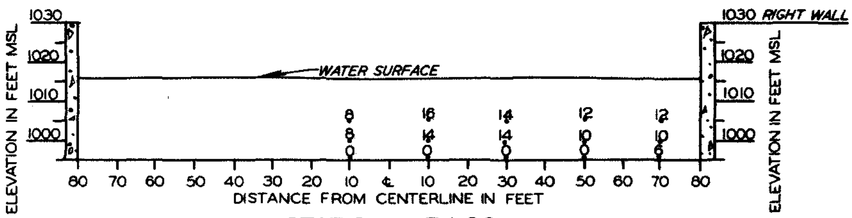
TAILWATER ELEVATION 1017.0



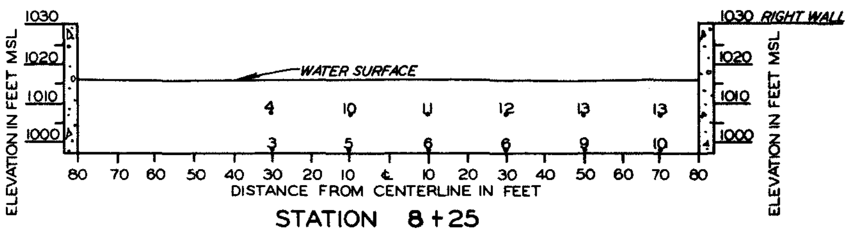

STATION 6+70



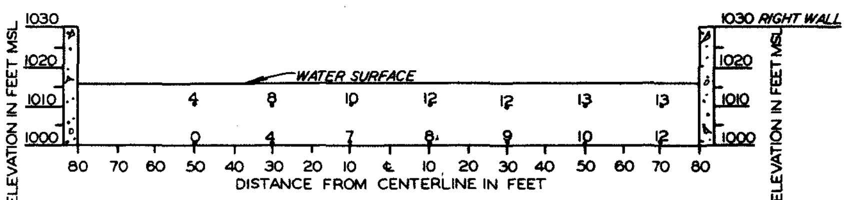

STATION 7+65



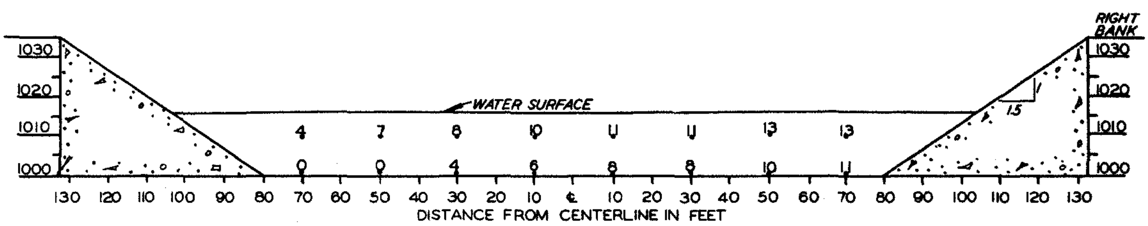

STATION 7+86




STATION 8+25




STATION 8+75




STATION 9+25

NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

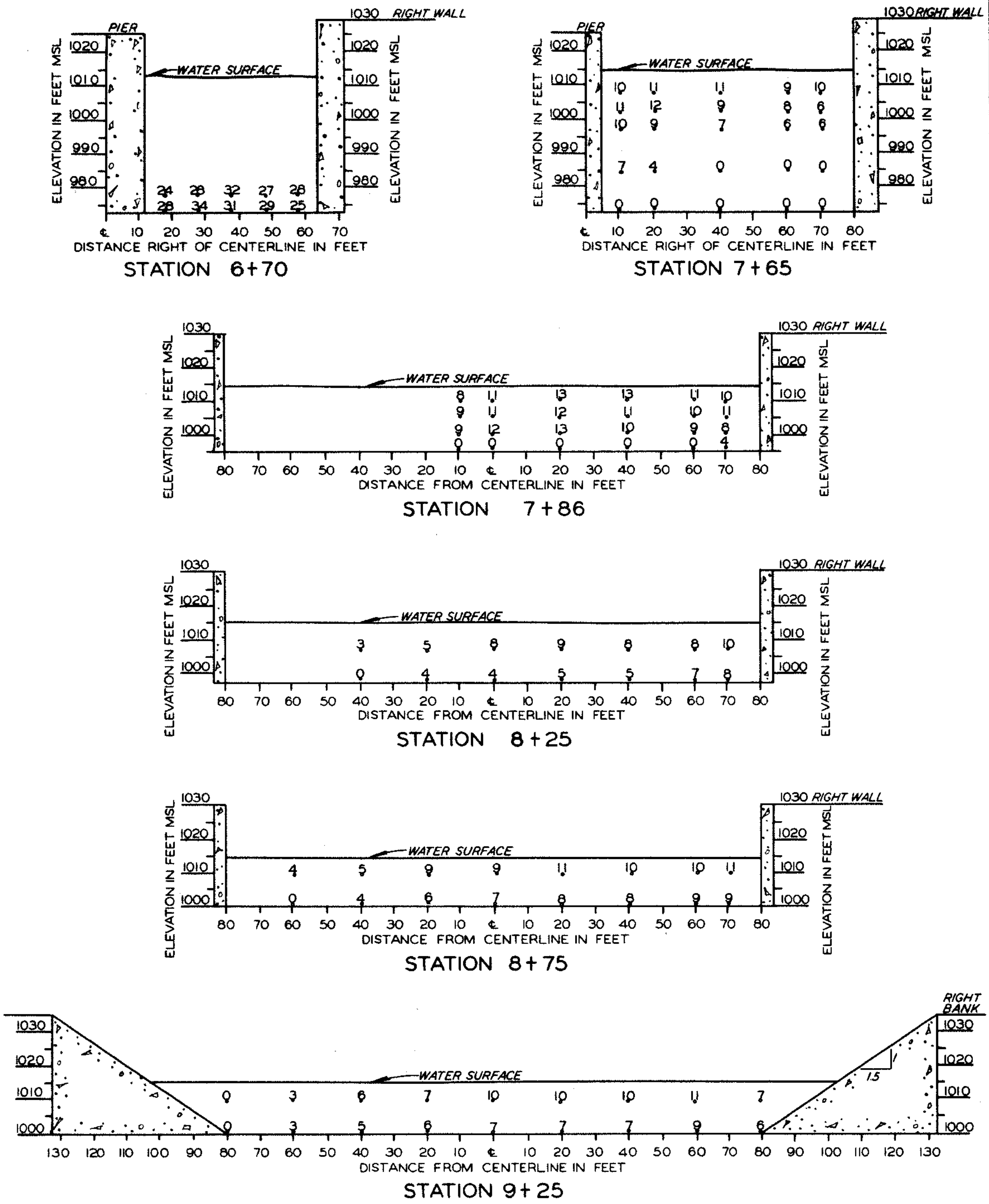
VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR.

## VELOCITIES

ORIGINAL DESIGN

| | |
|---|---|
| DISCHARGE | 19,500 CFS |
| TAILWATER ELEVATION | 1016.0 |
| GATE OPENING | 3/4 |




NOTE VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR

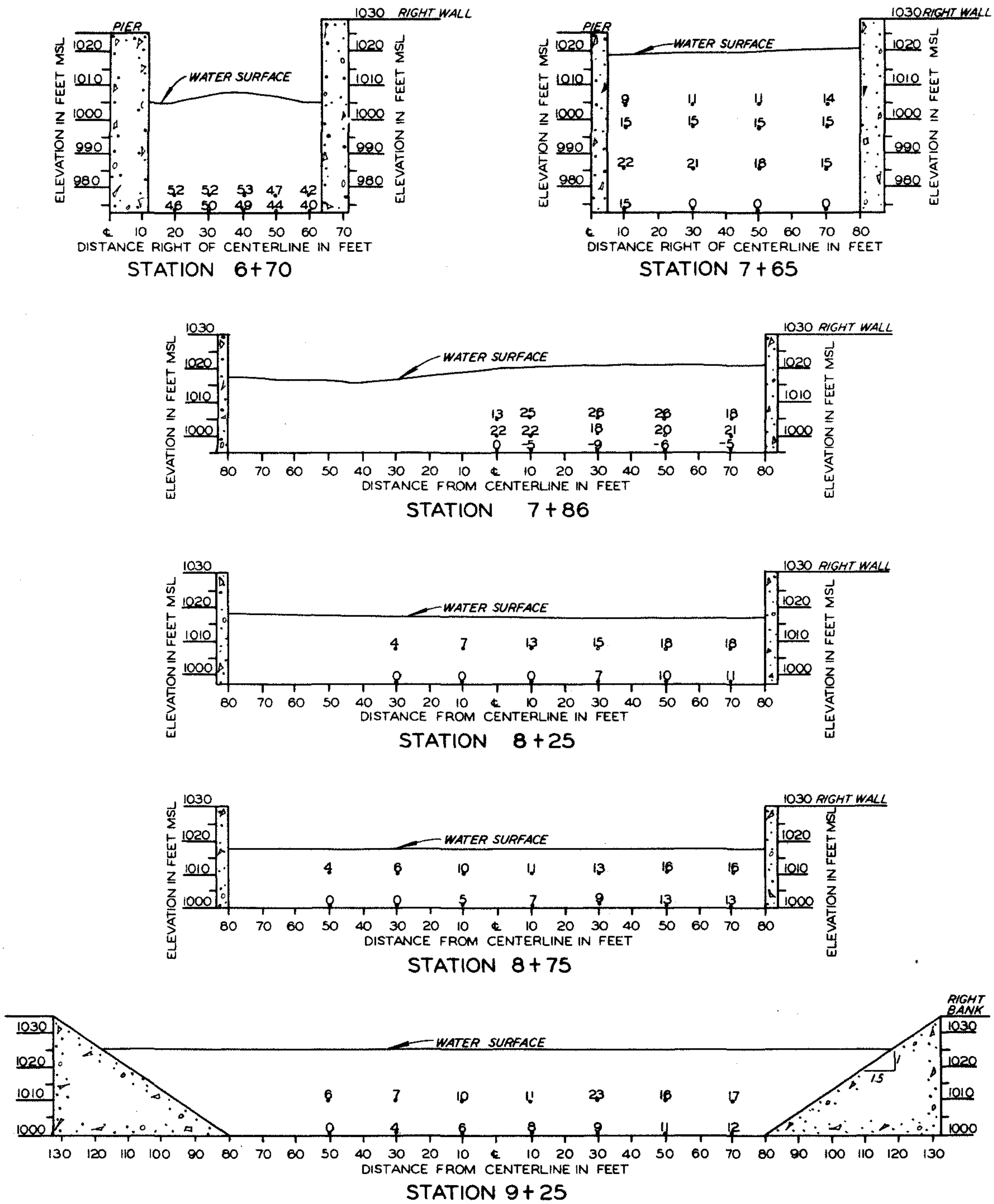
## VELOCITIES

ORIGINAL DESIGN

DISCHARGE 15,000 CFS

TAILWATER ELEVATION 1014.5

PLATE 18




NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR

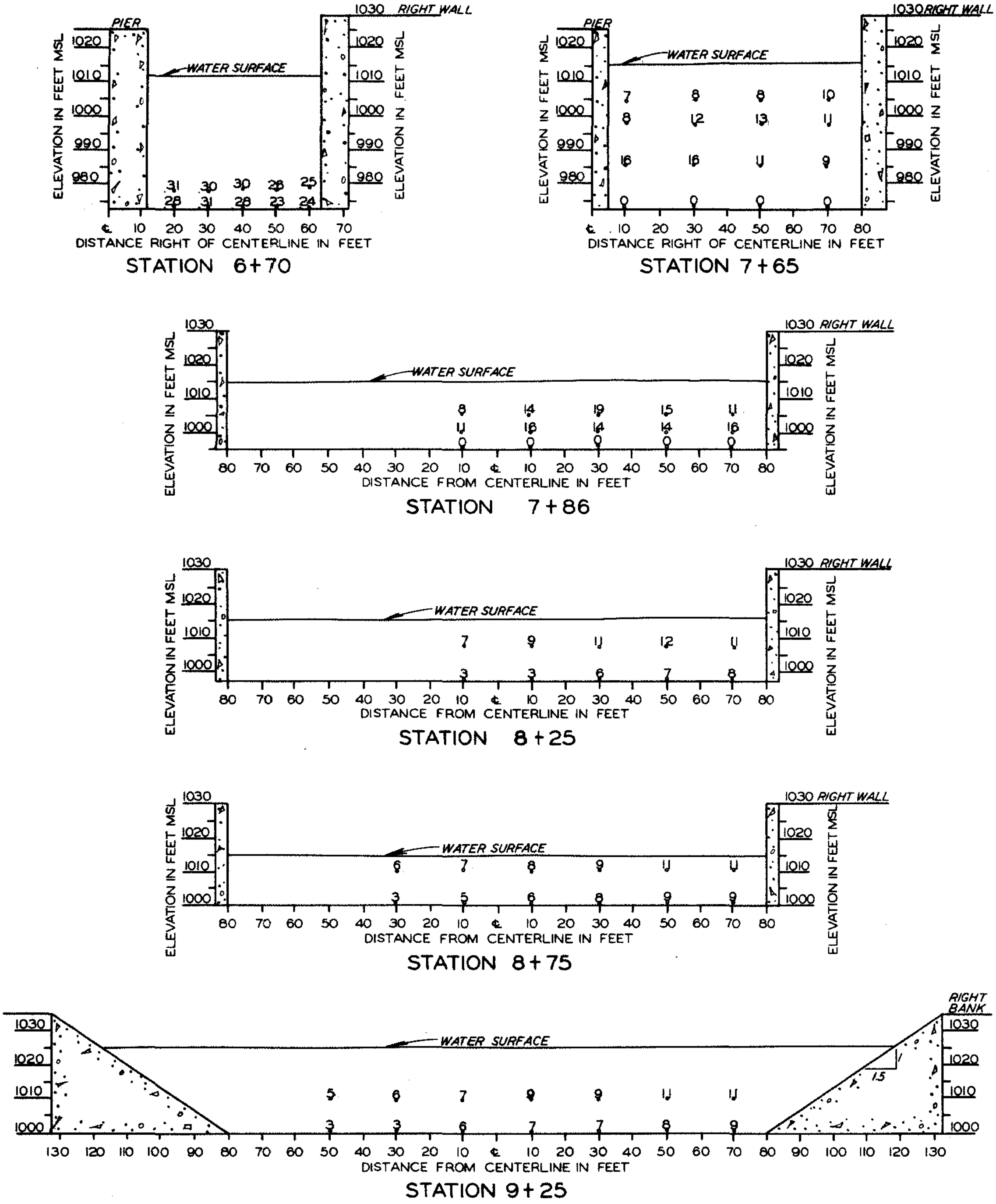
**VELOCITIES**

**WITHOUT BAFFLE PIERS**

ORIGINAL DESIGN

DISCHARGE 22,500 CFS

TAILWATER ELEVATION 1017.0




NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

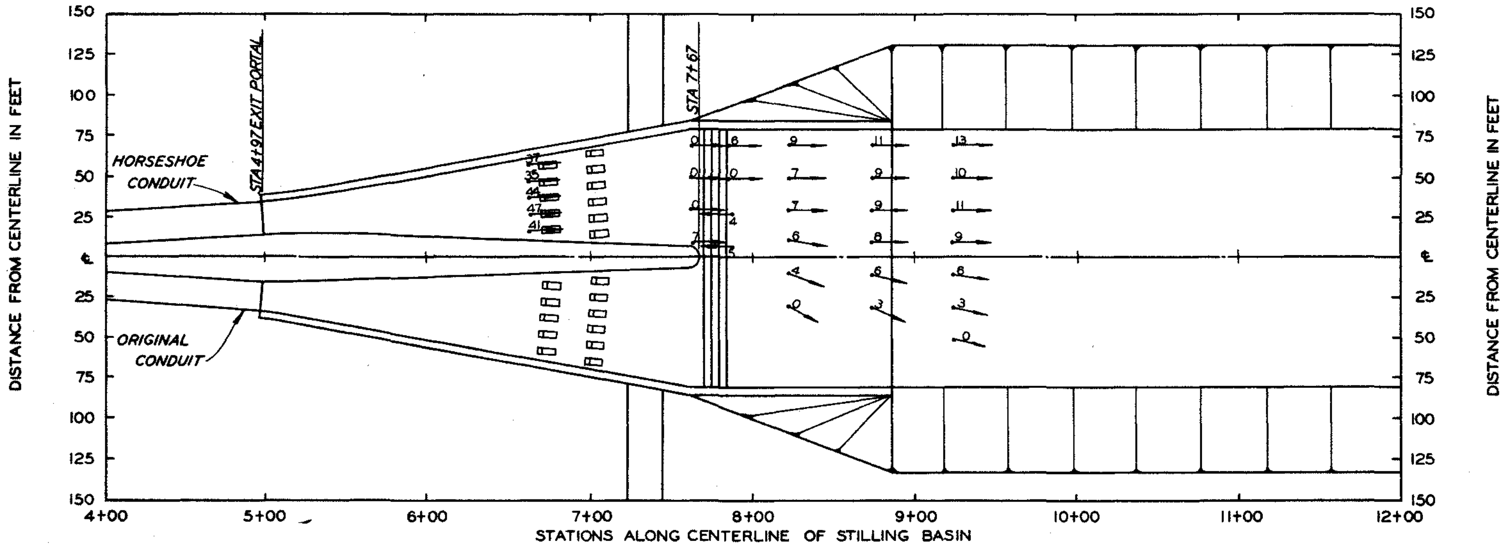
BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR.

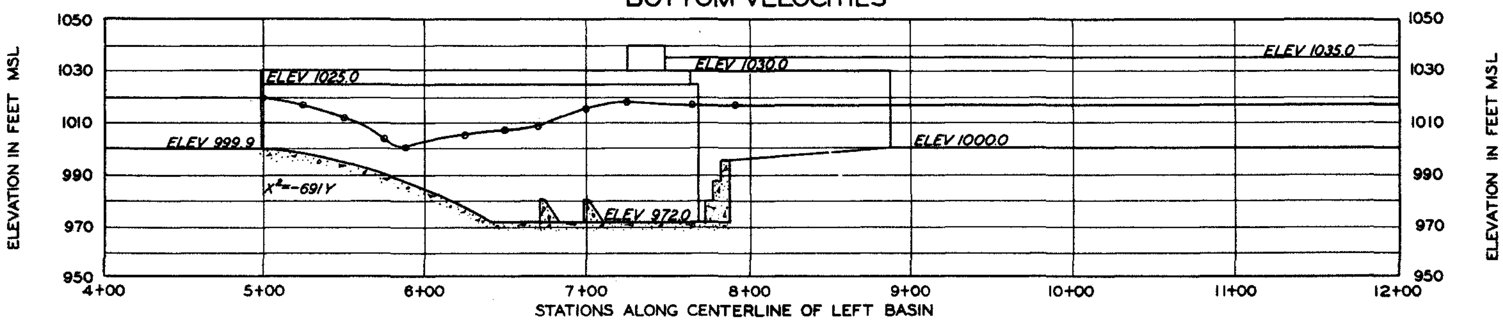
## VELOCITIES
## WITHOUT BAFFLE PIERS

ORIGINAL DESIGN

DISCHARGE 15,000 CFS

TAILWATER ELEVATION 1014.5



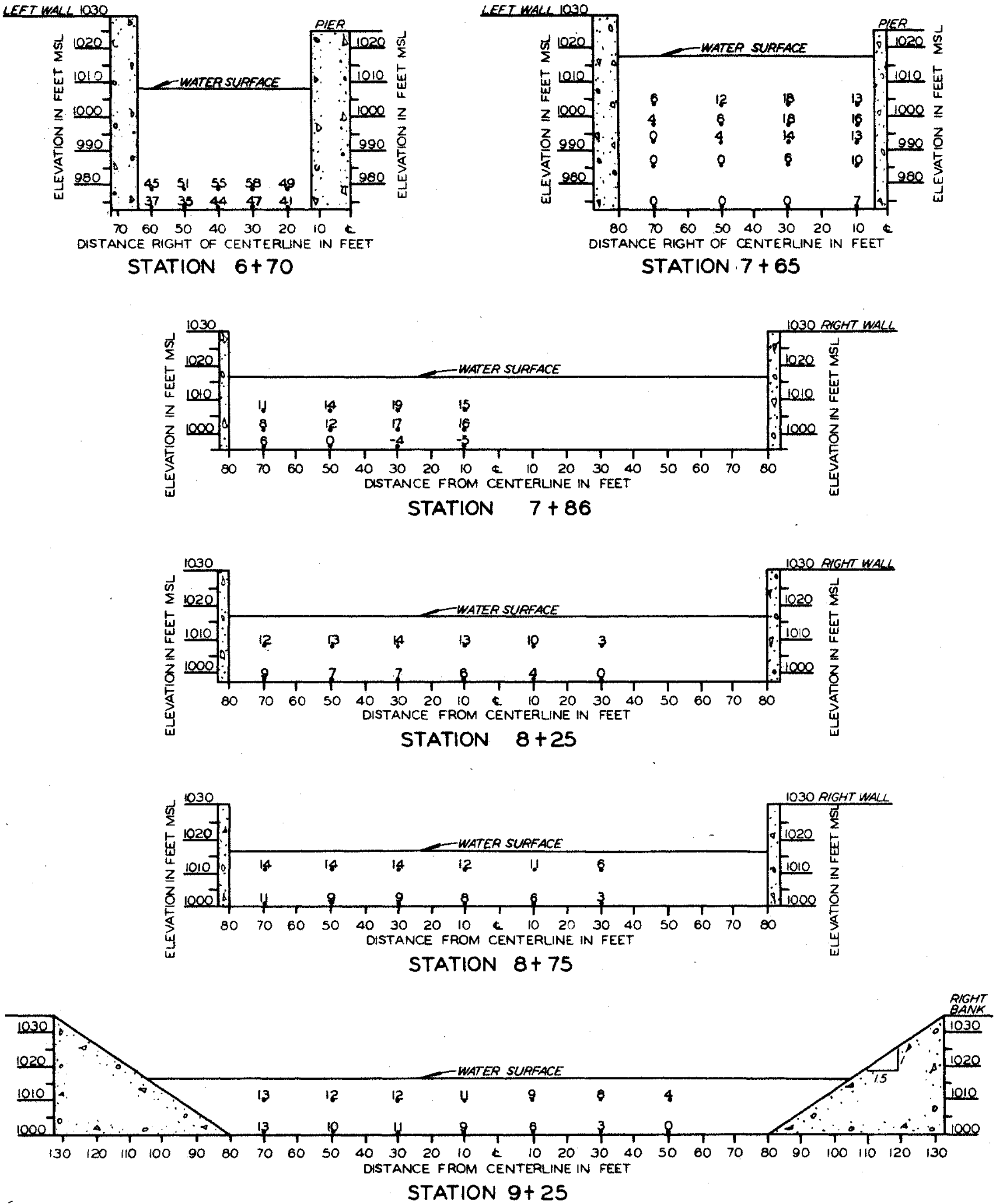




NOTE: STATION 0+00 IS THE AXIS OF DAM.
EXIT CHANNEL MOLDED IN CEMENT MORTAR.
VELOCITY MEASUREMENTS TAKEN 0.5 FT OFF BOTTOM. ZERO VELOCITY INDICATES SOME MOVEMENT IN DIRECTION SHOWN.
VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

# BOTTOM VELOCITIES AND WATER-SURFACE PROFILE

## ORIGINAL DESIGN STILLING BASIN LEFT HORSESHOE-SHAPED CONDUIT

| | |
|---|---|
| DISCHARGE | 22,500 CFS |
| TAILWATER ELEVATION | 1017.0 |




NOTE VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND

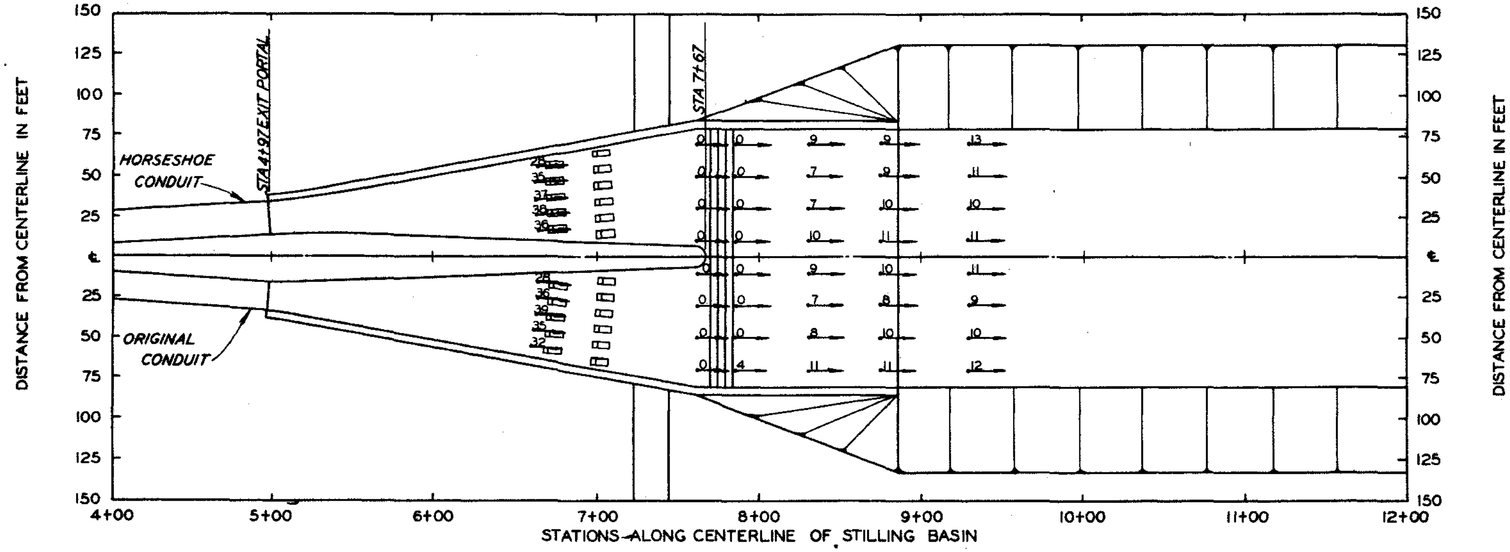
VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW

BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR

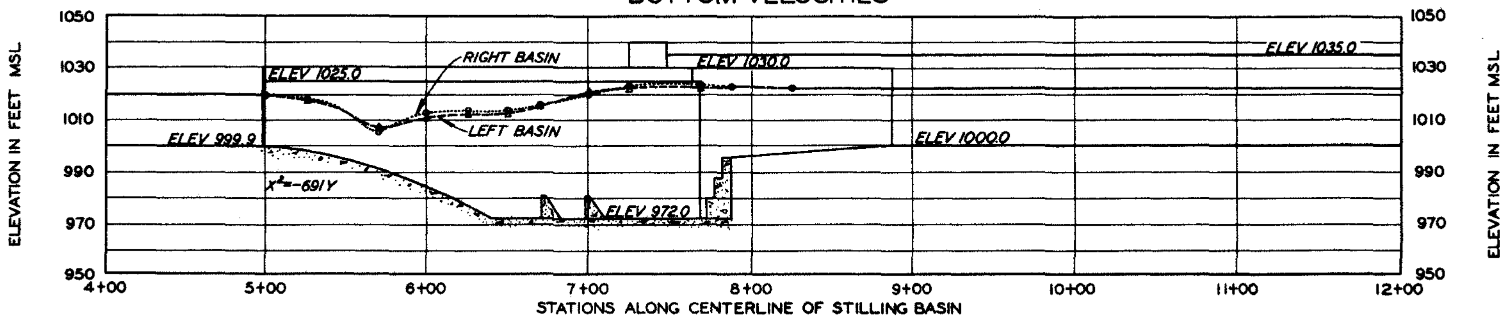
## VELOCITIES

### ORIGINAL DESIGN STILLING BASIN
### LEFT HORSESHOE SHAPED CONDUIT

| | |
|---|---|
| DISCHARGE | 22,500 C F S |
| TAILWATER ELEVATION | 1017.0 |
| GATE OPENING | FULL |




BOTTOM VELOCITIES



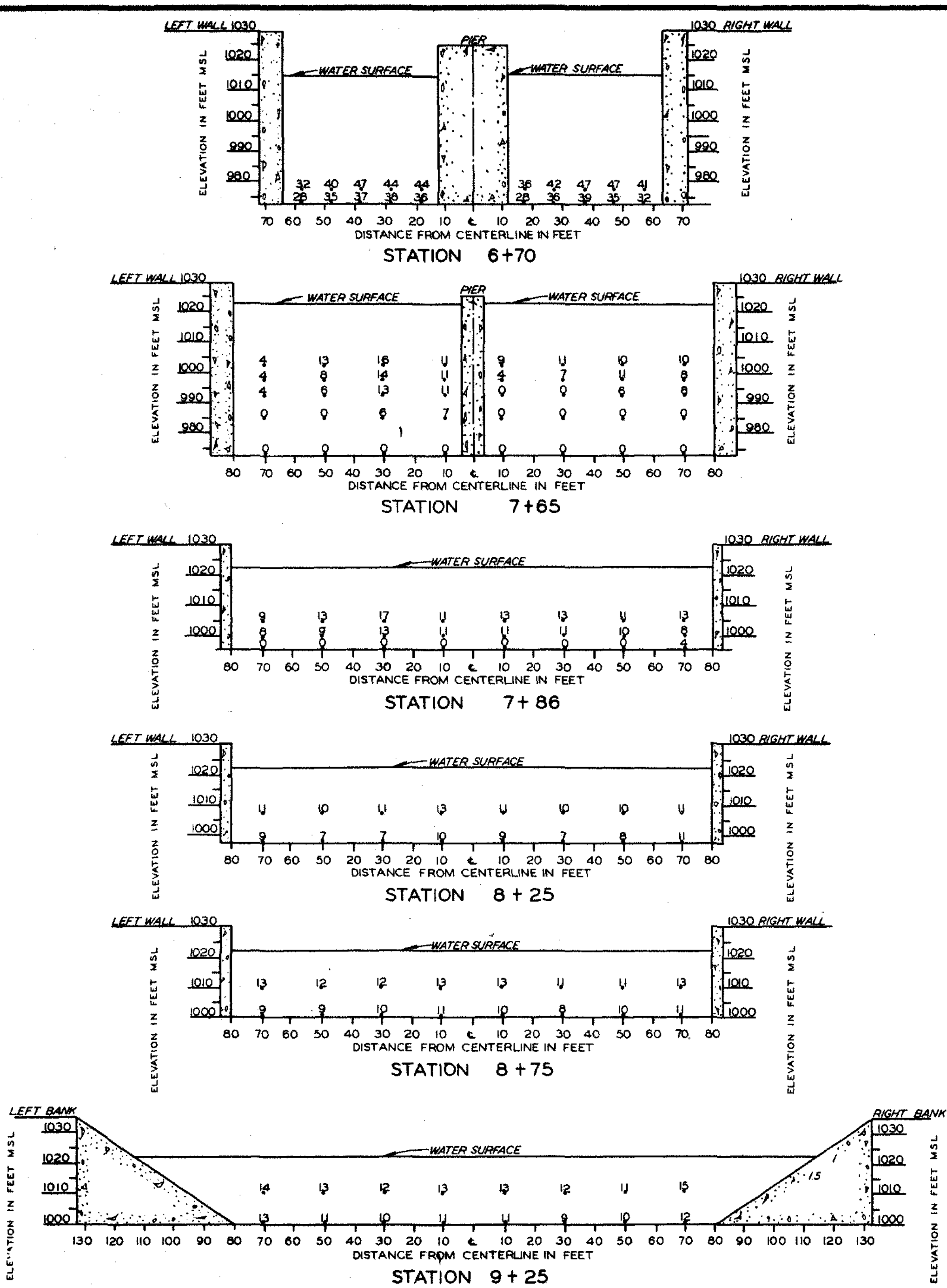

WATER-SURFACE PROFILE

NOTE: STATION 0+00 IS THE AXIS OF DAM.
EXIT CHANNEL MOLDED IN CEMENT MORTAR.
VELOCITY MEASUREMENTS TAKEN 0.5 FT OFF BOTTOM. ZERO VELOCITY INDICATES SOME MOVEMENT IN DIRECTION SHOWN.
VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

# BOTTOM VELOCITIES AND WATER-SURFACE PROFILE

## ORIGINAL DESIGN STILLING BASIN TWIN CONDUIT OPERATION

DISCHARGE 45,000 CFS
TAILWATER ELEVATION 1022.2




NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

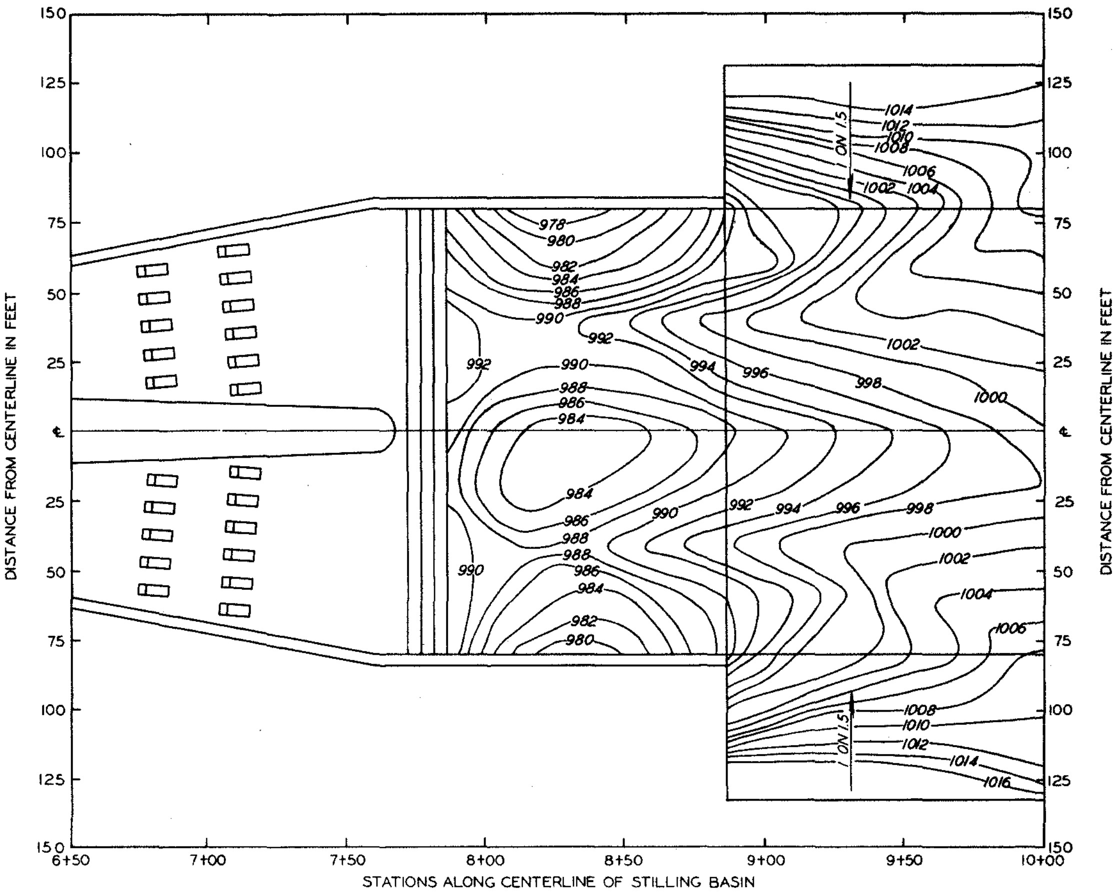
BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR

# VELOCITIES

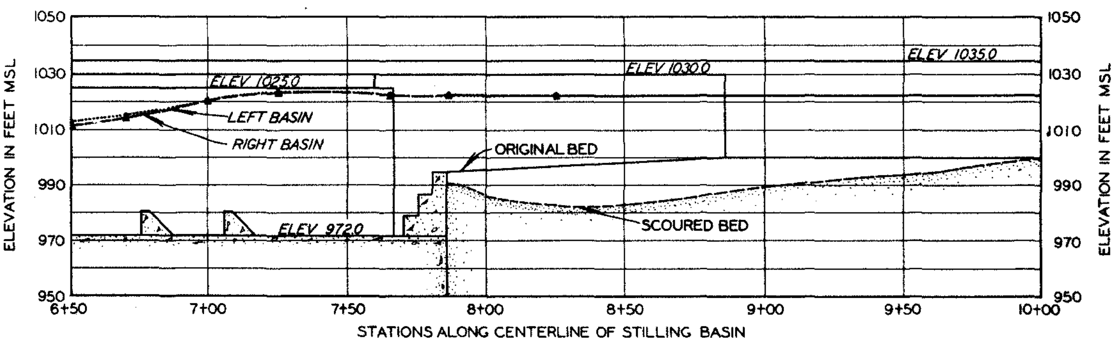
## ORIGINAL DESIGN STILLING BASIN TWIN CONDUIT OPERATION

DISCHARGE 45 000 CFS

TAILWATER ELEVATION 1022.2




SCOUR PATTERN



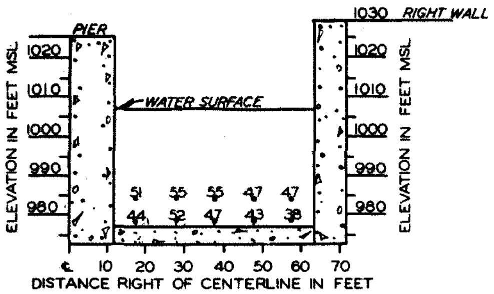

SCOUR AND WATER SURFACE PROFILES

NOTE: EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.
MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.
WATER SURFACE PROFILE OBTAINED WITH BED MOLDED IN CEMENT MORTAR.

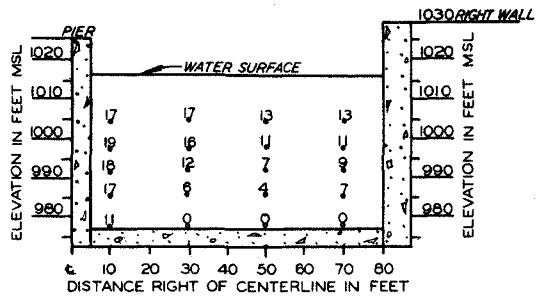
# SCOUR PATTERN

## ORIGINAL DESIGN STILLING BASIN
## TWIN CONDUIT OPERATION

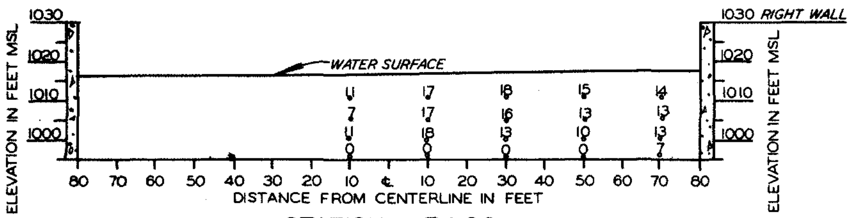
| | |
|---|---|
| DISCHARGE | 45,000 CFS |
| TAILWATER ELEVATION | 1022.2 |



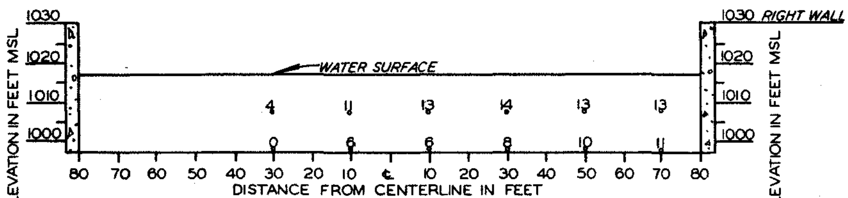

STATION 6+70



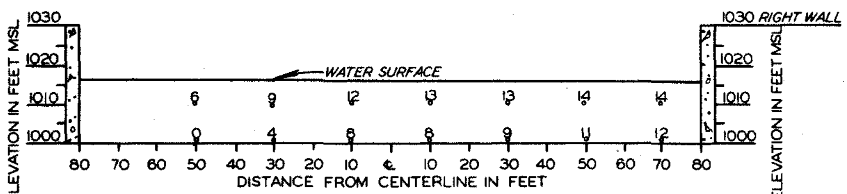

STATION 7+65



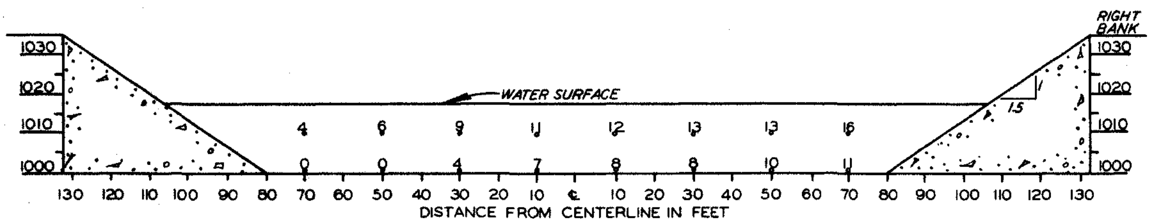

STATION 7+86




STATION 8+25




STATION 8+75




STATION 9+25

NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

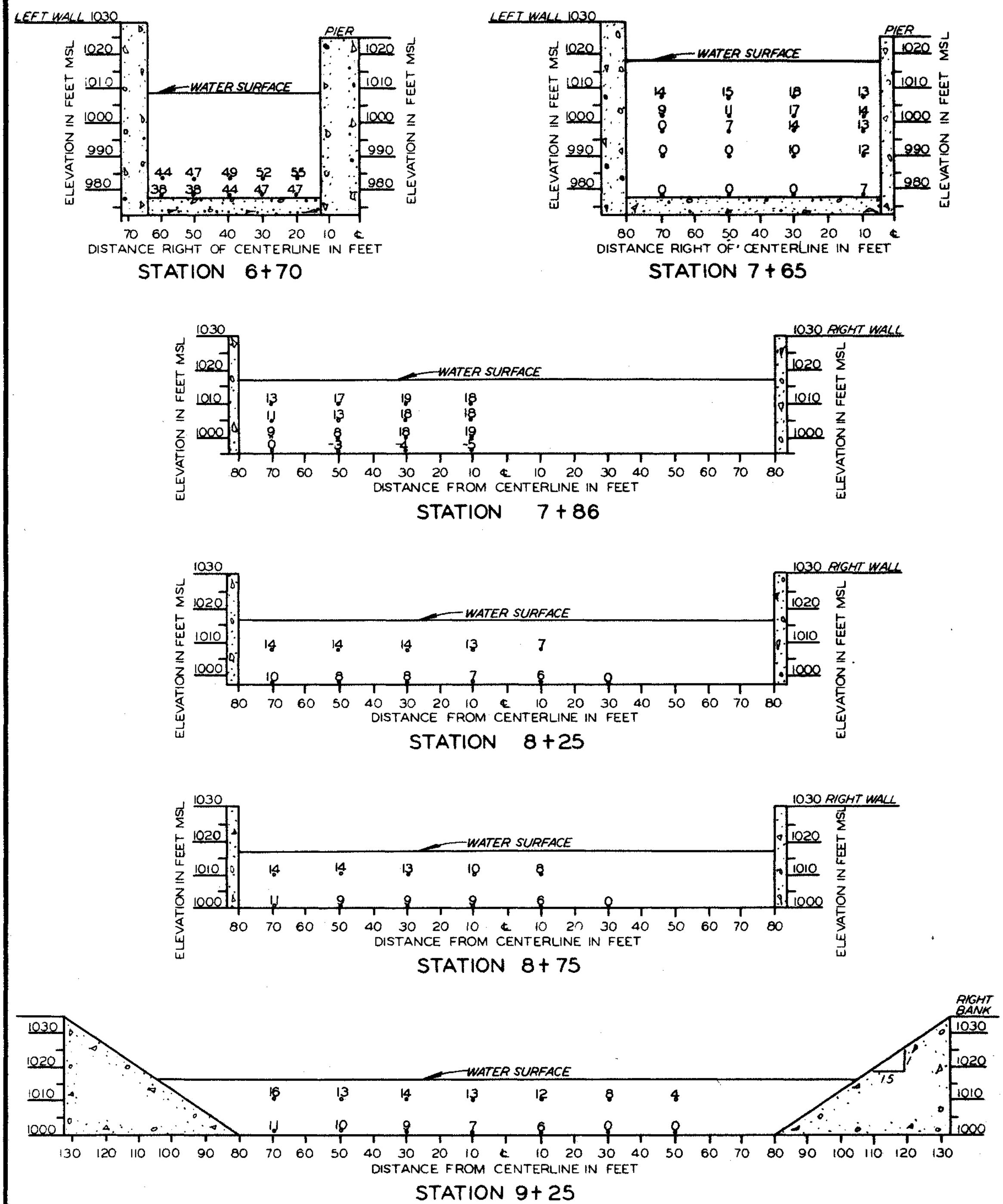
VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR.

# VELOCITIES

## ALTERNATE BASIN DESIGN 1
## RIGHT CONDUIT FLOW

DISCHARGE 22,500 C F S
TAILWATER ELEVATION 1017.0




NOTE VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND

VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW

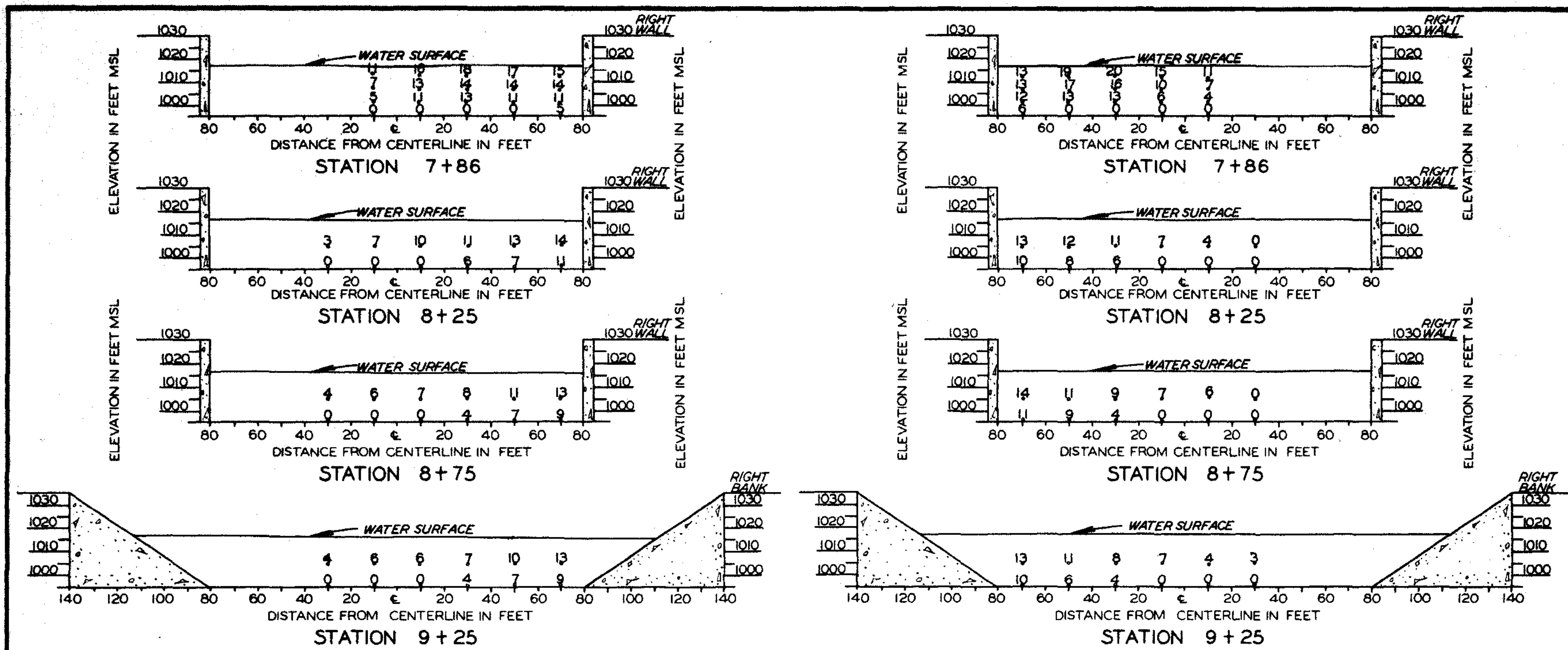
BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR

## VELOCITIES

### ALTERNATE BASIN DESIGN I
### LEFT CONDUIT FLOW

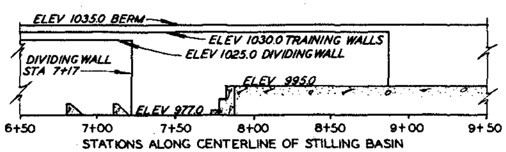
| | |
|---|---|
| DISCHARGE | 22,500 C F S |
| TAILWATER ELEVATION | 1017.0 |

PLATE 28




DISCHARGE 22,500 CFS THROUGH RIGHT CONDUIT

DISCHARGE 22,500 CFS THROUGH LEFT CONDUIT




CENTERLINE ELEVATION

NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND

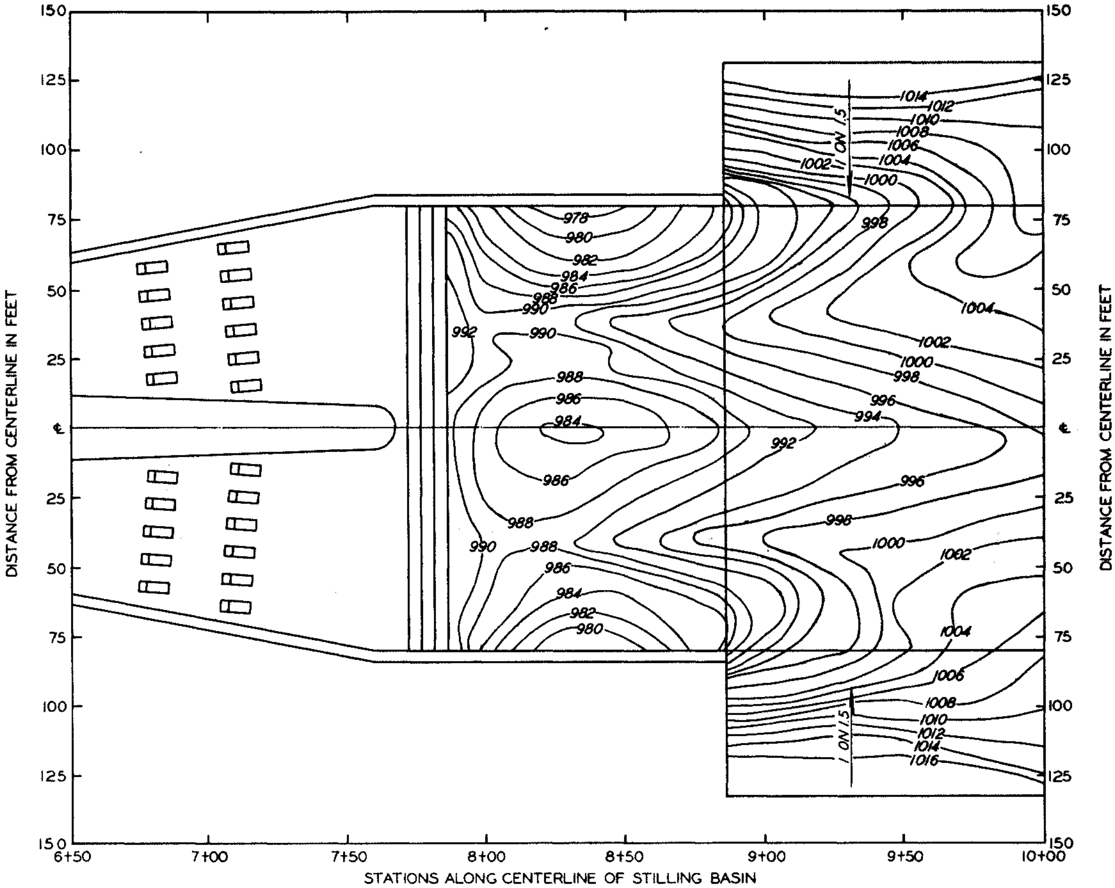
VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW

BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR

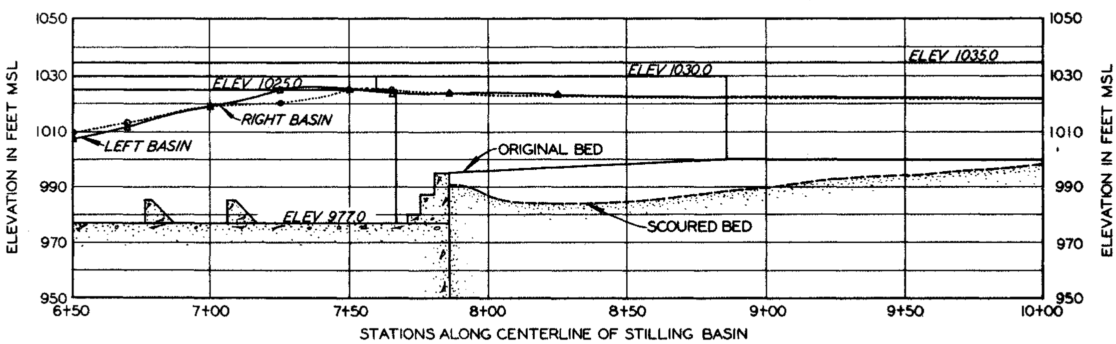
# VELOCITY COMPARISON

## ALTERNATE BASIN DESIGN 1
## RIGHT CONDUIT VS LEFT CONDUIT FLOW

| | |
|---|---|
| STILLING BASIN FLOOR AT ELEVATION | 977.0 |
| DIVIDING WALL AT STATION | 7+17 |
| EXIT CHANNEL ELEVATION | 995.0 |
| TAILWATER ELEVATION | 1017.0 |




SCOUR PATTERN

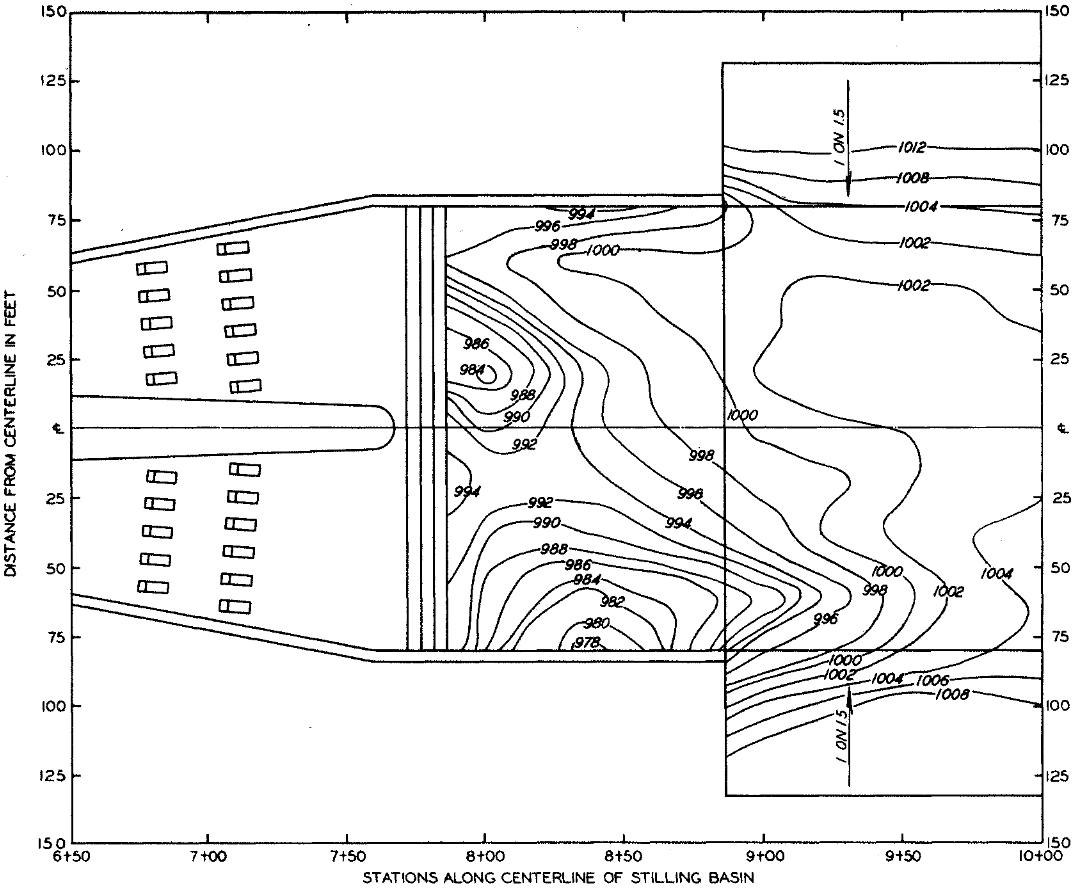



SCOUR AND WATER SURFACE PROFILES

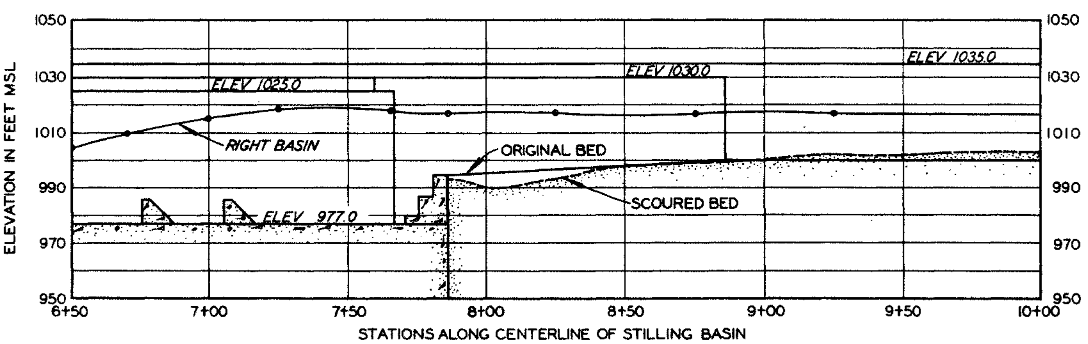
NOTE: EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.
MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.
WATER SURFACE PROFILE OBTAINED WITH BED MOLDED IN CEMENT MORTAR.

# SCOUR PATTERN
## ALTERNATE BASIN DESIGN 1
## TWIN CONDUIT OPERATION

DISCHARGE 45,000 CFS
TAILWATER ELEVATION 1022.2




SCOUR PATTERN




SCOUR AND WATER SURFACE PROFILES

NOTE: EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.

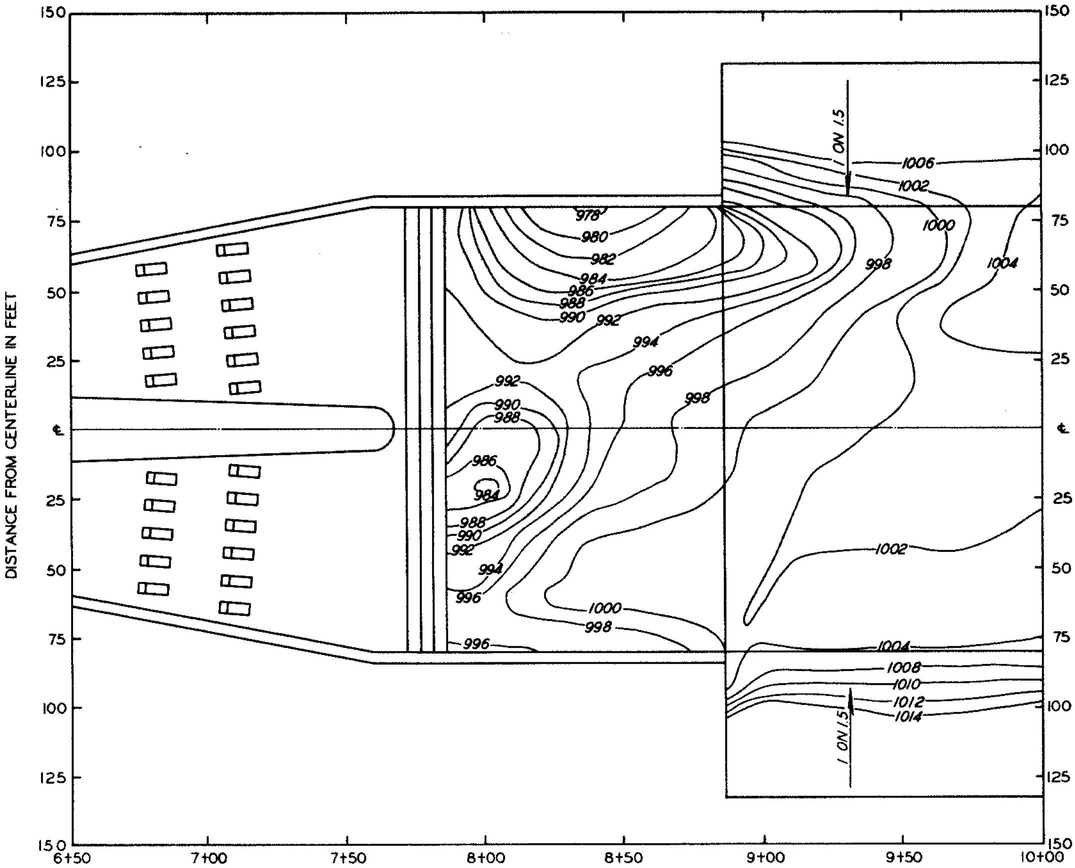
MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.

WATER SURFACE PROFILE OBTAINED WITH BED MOLDED IN CEMENT MORTAR.

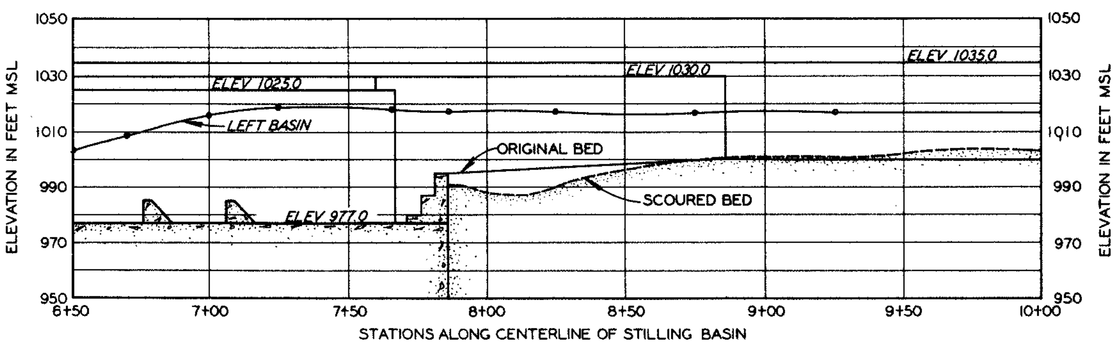
## SCOUR PATTERN

### ALTERNATE BASIN DESIGN 1
### RIGHT CONDUIT FLOW

DISCHARGE 22,500 CFS
TAILWATER ELEVATION 1017.0




SCOUR PATTERN




SCOUR AND WATER SURFACE PROFILES

NOTE: EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.

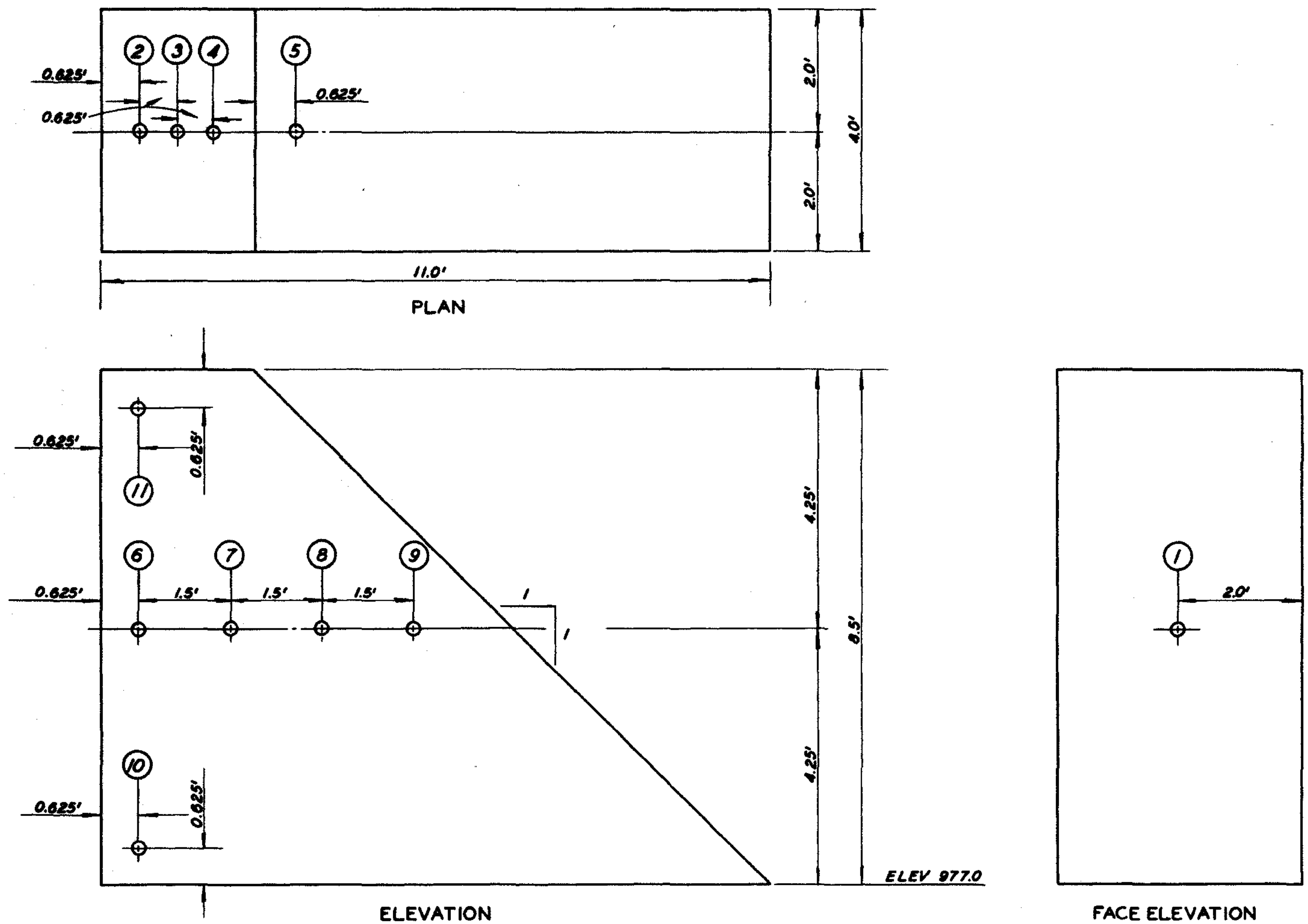
MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.

WATER SURFACE PROFILE OBTAINED WITH BED MOLDED IN CEMENT MORTAR.

# SCOUR PATTERN

## ALTERNATE BASIN DESIGN 1
## LEFT CONDUIT FLOW

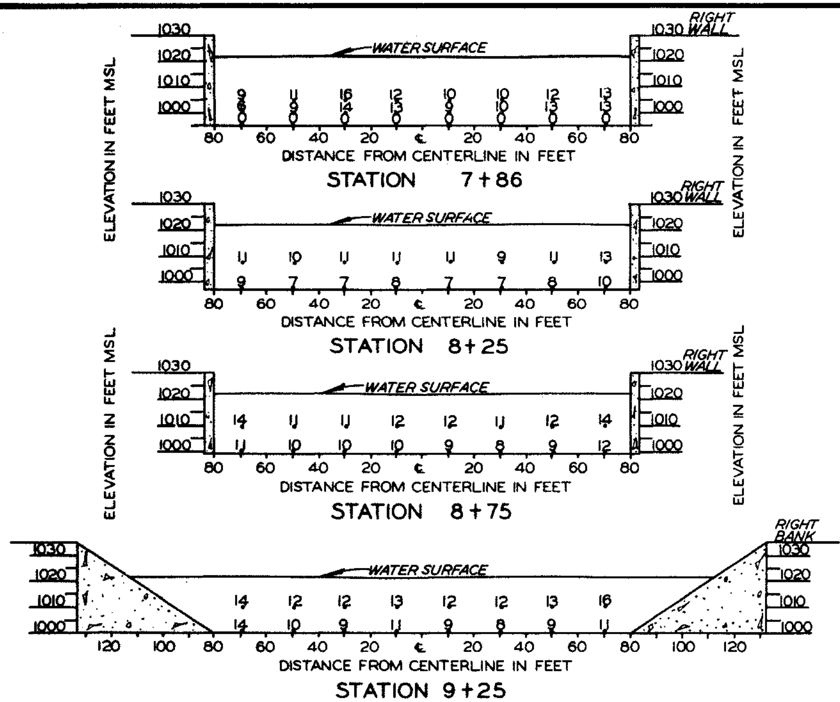
DISCHARGE 22,500 CFS
TAILWATER ELEVATION 1017.0

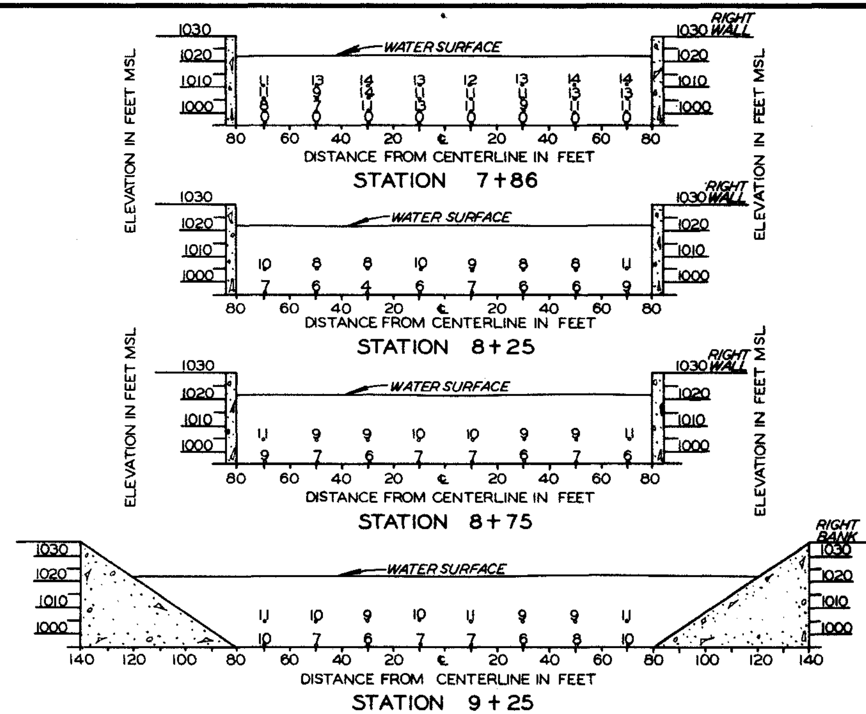


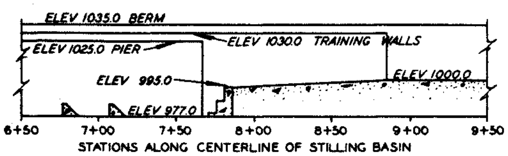

NOTE: ELEVATIONS ARE IN FEET MEAN SEA LEVEL.

PIEZOMETER LOCATIONS
ORIGINAL DESIGN BAFFLE PIERS

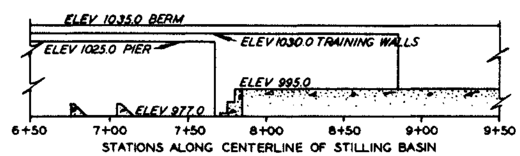
SCALE
1 0 1 2 3 4 FT




ORIGINAL EXIT CHANNEL




CHANNEL ELEVATION 995.0

NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

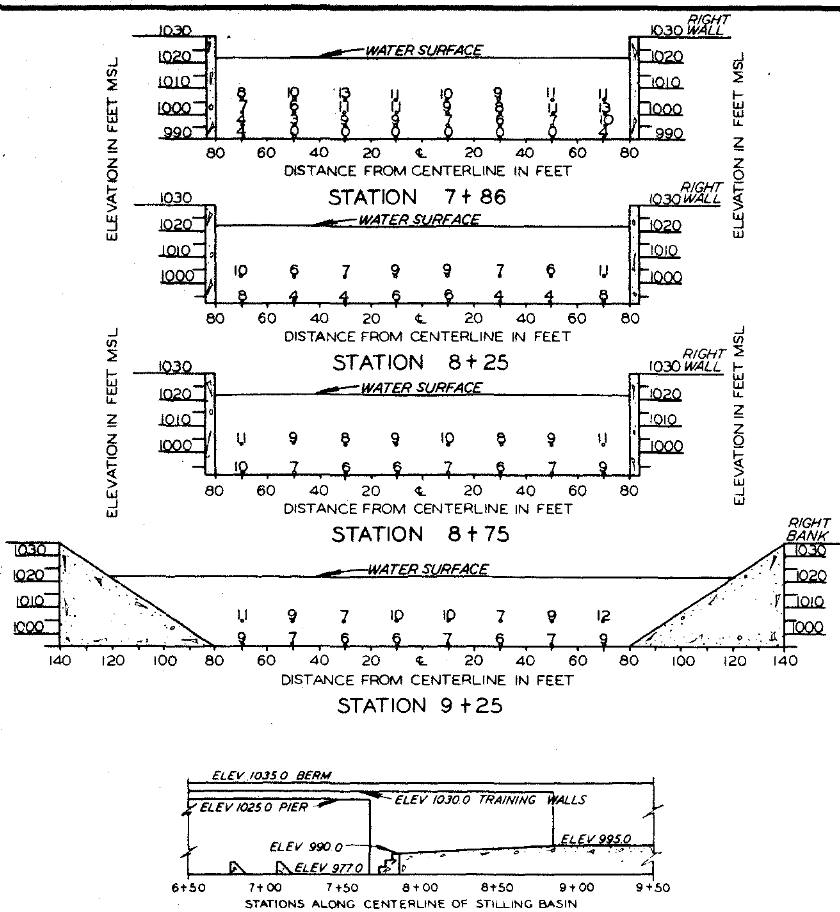
BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR.

## VELOCITY COMPARISON
## ALTERNATE BASIN DESIGN 1

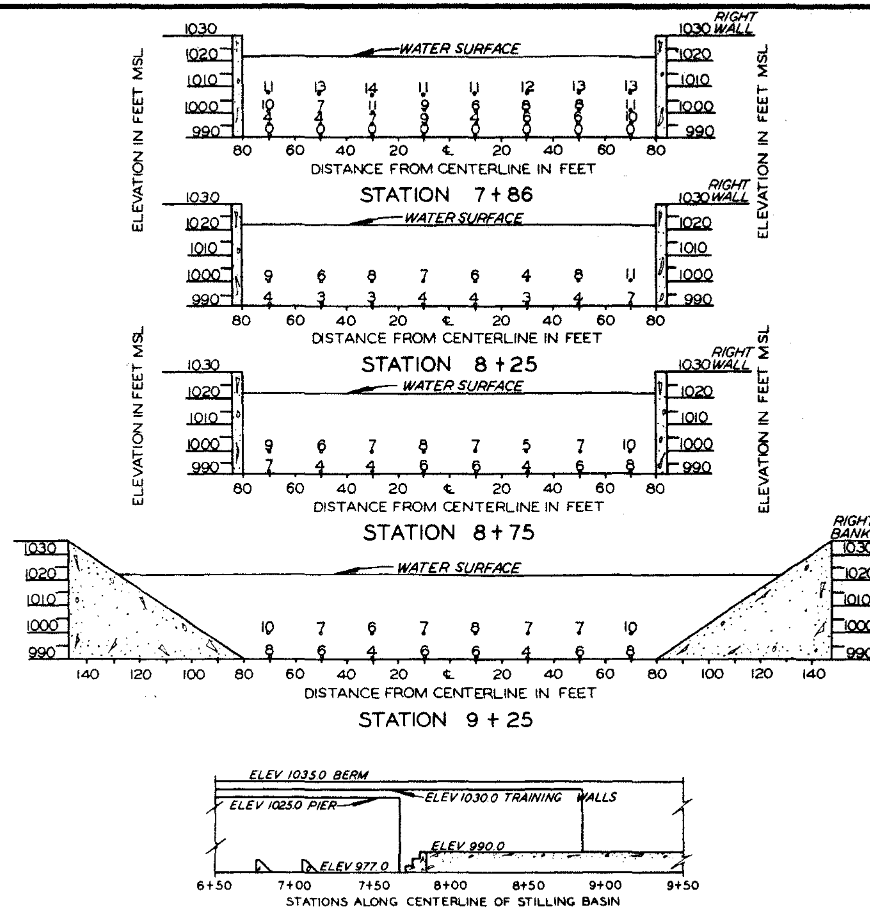
ORIGINAL EXIT CHANNEL VS CHANNEL ELEVATION 995.0

| | |
|---|---|
| STILLING BASIN FLOOR AT ELEVATION | 977.0 |
| DISCHARGE | 45,000 C F S |
| TAILWATER ELEVATION | 1022.2 |

PLATE 34




END SILL ELEVATION 990.0 AND EXIT CHANNEL ELEVATION 995.0




END SILL AND EXIT CHANNEL ELEVATION 990.0

NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND

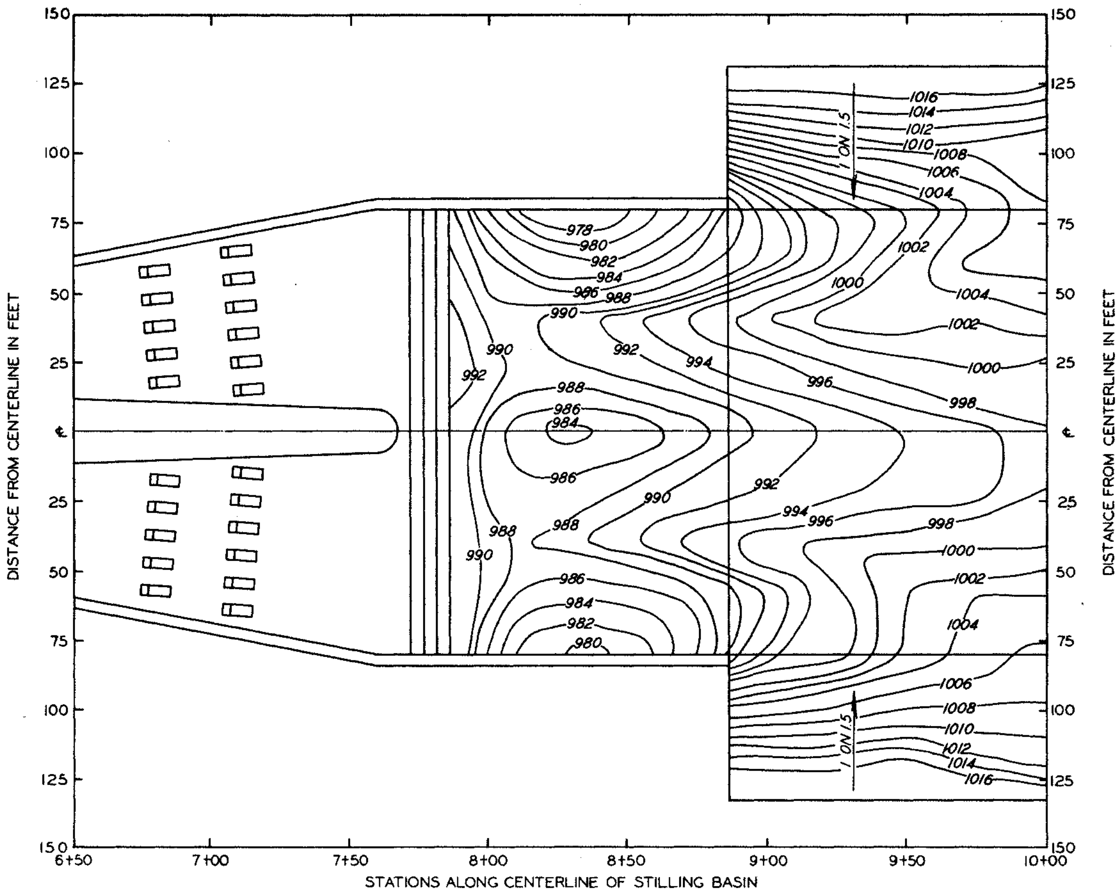
VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW

BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR

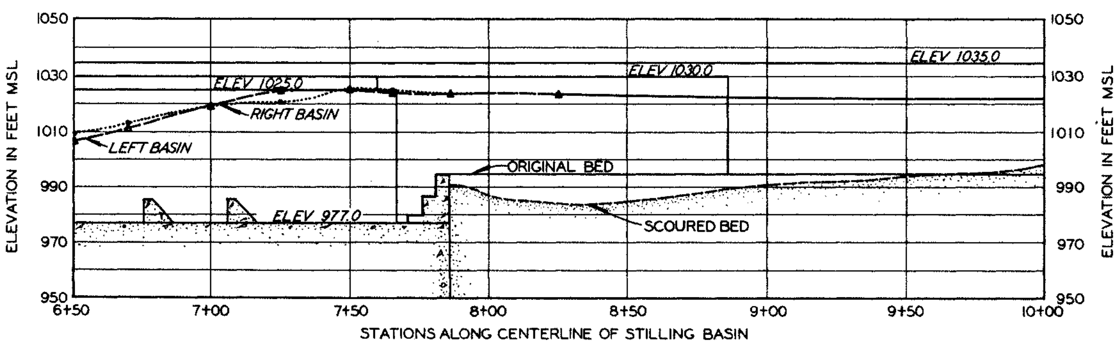
## VELOCITY COMPARISON

### END SILL ELEVATION 990.0 AND EXIT CHANNEL ELEVATIONS 995.0 AND 990.0

| | |
|---|---|
| STILLING BASIN FLOOR AT ELEVATION | 977.0 |
| DISCHARGE | 45,000 C F S |
| TAILWATER ELEVATION | 1022.2 |




SCOUR PATTERN




SCOUR AND WATER SURFACE PROFILE

NOTE: EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.

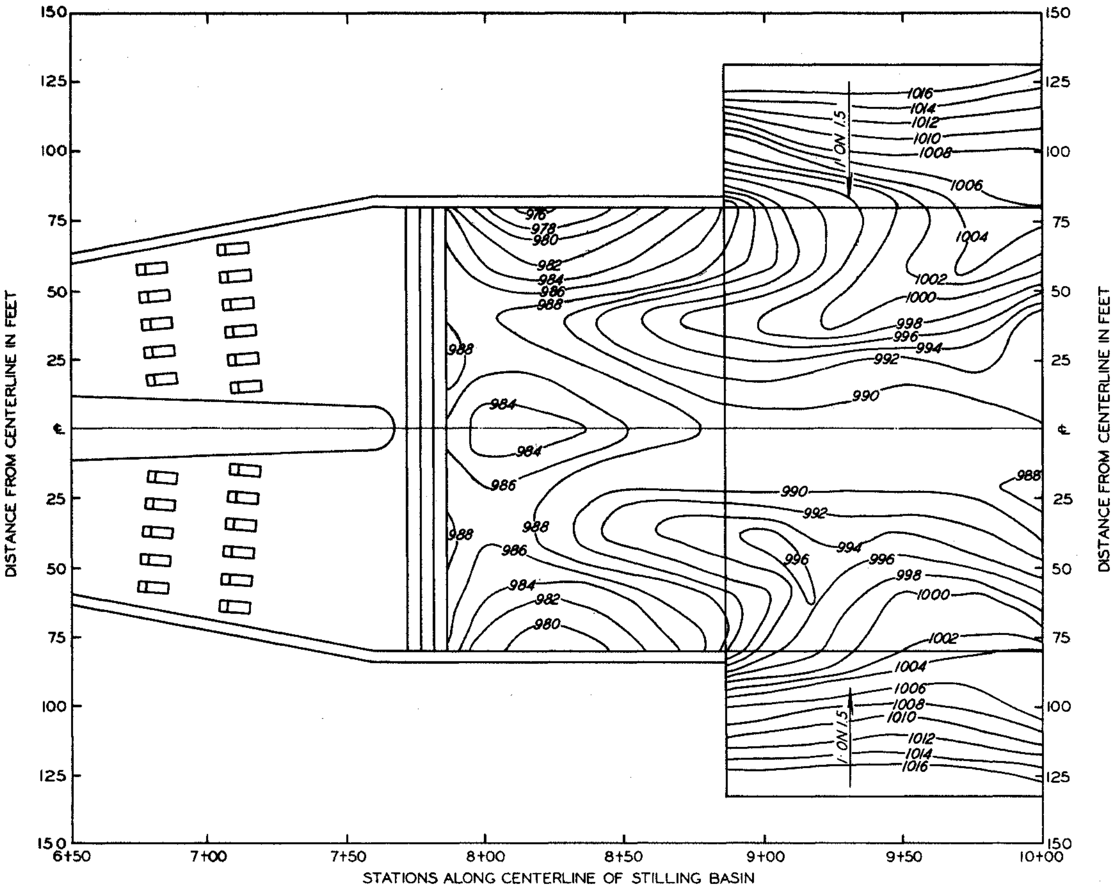
MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.

WATER SURFACE PROFILE OBTAINED WITH BED MOLDED IN CEMENT MORTAR.

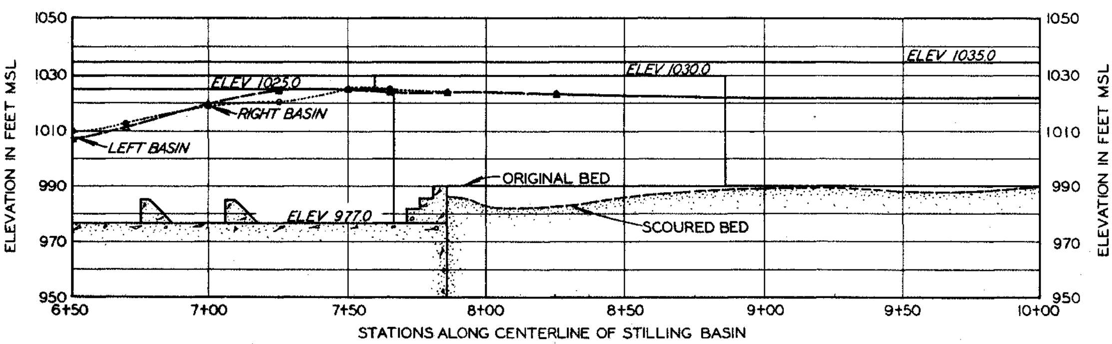
# SCOUR PATTERN

## ALTERNATE BASIN DESIGN 1
## EXIT CHANNEL ELEVATION 995.0

| | |
|---|---|
| DISCHARGE | 45,000 CFS |
| TAILWATER ELEVATION | 1022.2 |
| END SILL ELEVATION | 995.0 |




SCOUR PATTERN



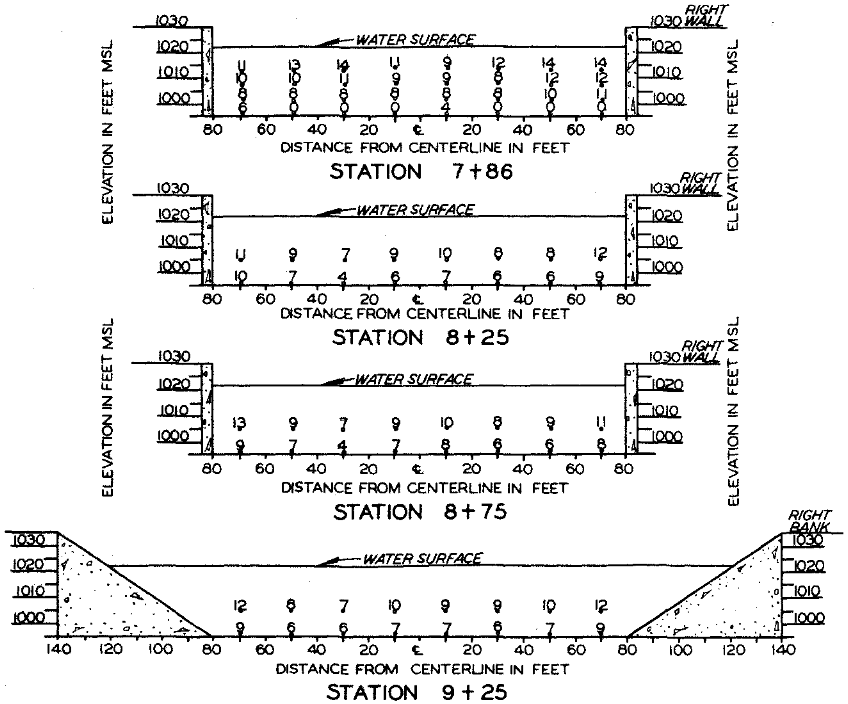

SCOUR AND WATER SURFACE PROFILES

NOTE: EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.
MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.
WATER SURFACE PROFILE OBTAINED WITH BED MOLDED IN CEMENT MORTAR.

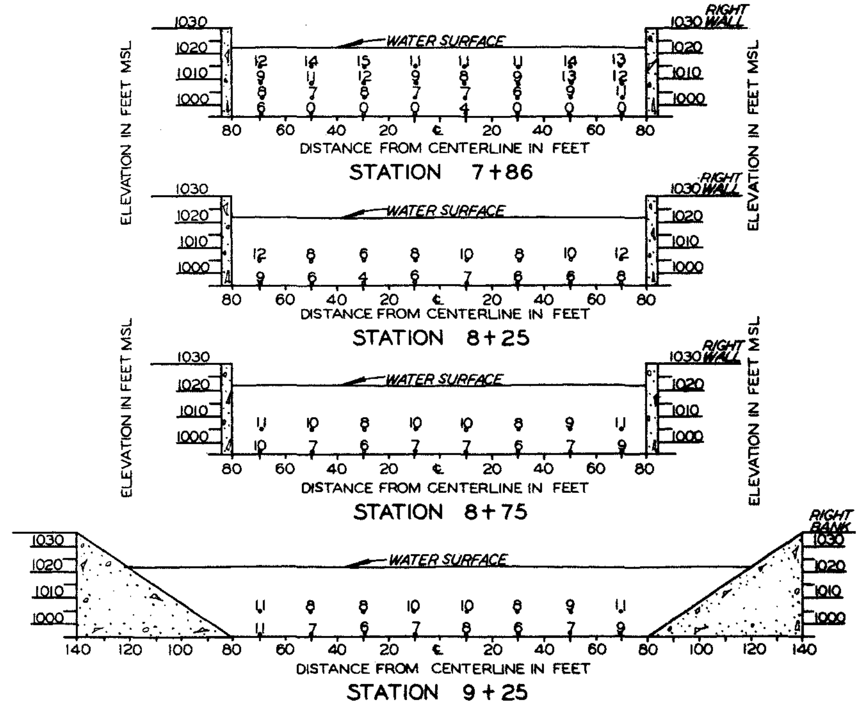
# SCOUR PATTERN

## ALTERNATE BASIN DESIGN 1
## EXIT CHANNEL ELEVATION 990.0

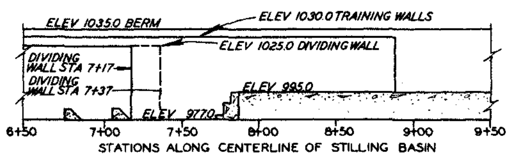
| | |
|---|---|
| DISCHARGE | 45,000 CFS |
| TAILWATER ELEVATION | 1022.2 |
| END SILL ELEVATION | 990.0 |




DIVIDING WALL SHORTENED 50 FEET TO STATION 7+17




DIVIDING WALL SHORTENED 30 FEET TO STATION 7+37




CENTERLINE ELEVATION INDICATING DIVIDING WALL LENGTHS

NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

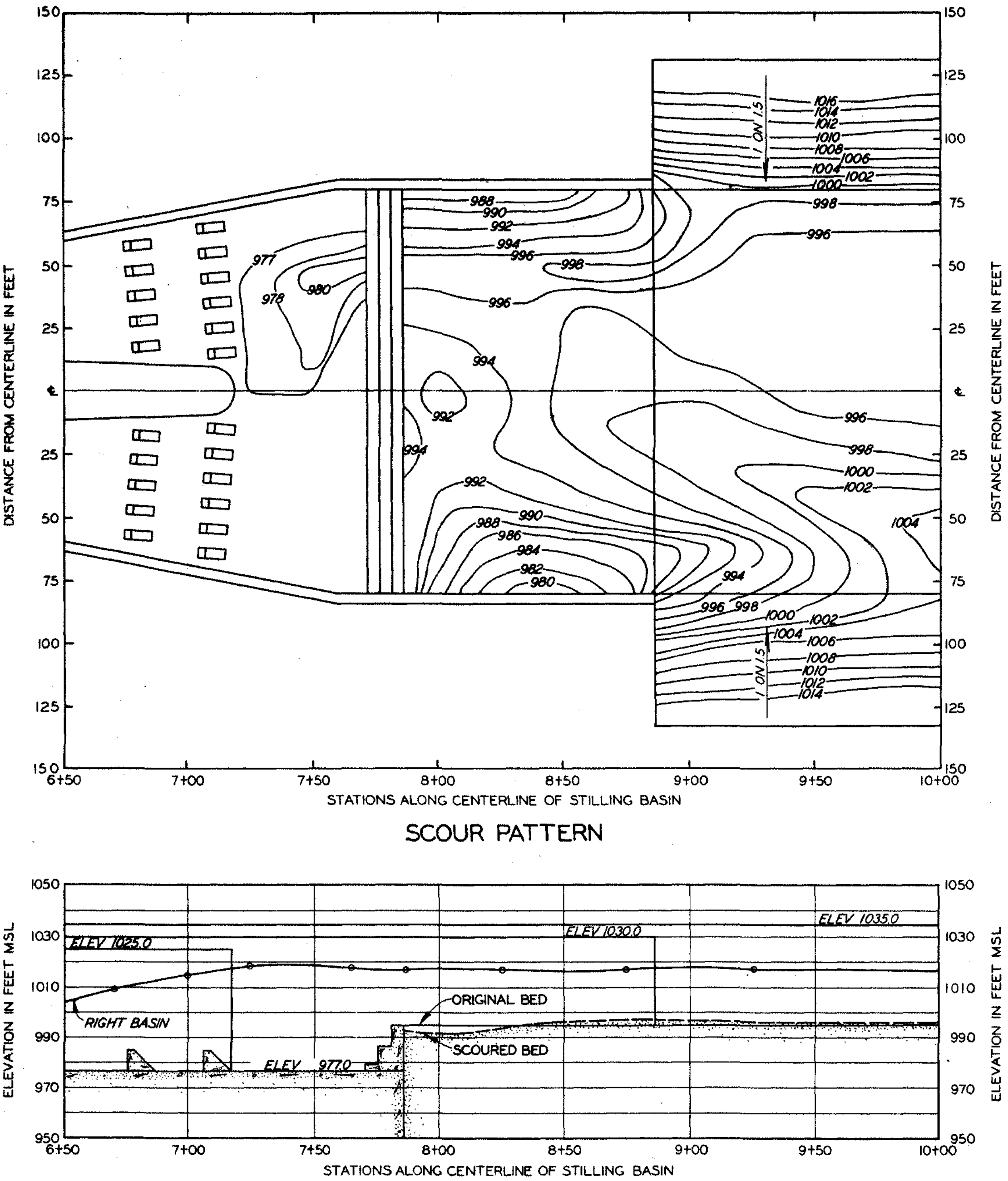
VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR.

# VELOCITY COMPARISON

## STILLING BASIN DIVIDING WALL SHORTENED 50 AND 30 FT

| | |
|---|---|
| STILLING BASIN FLOOR AT ELEVATION 977.0 | |
| DISCHARGE | 45,000 C F S |
| TAILWATER | 1022.2 |




SCOUR PATTERN

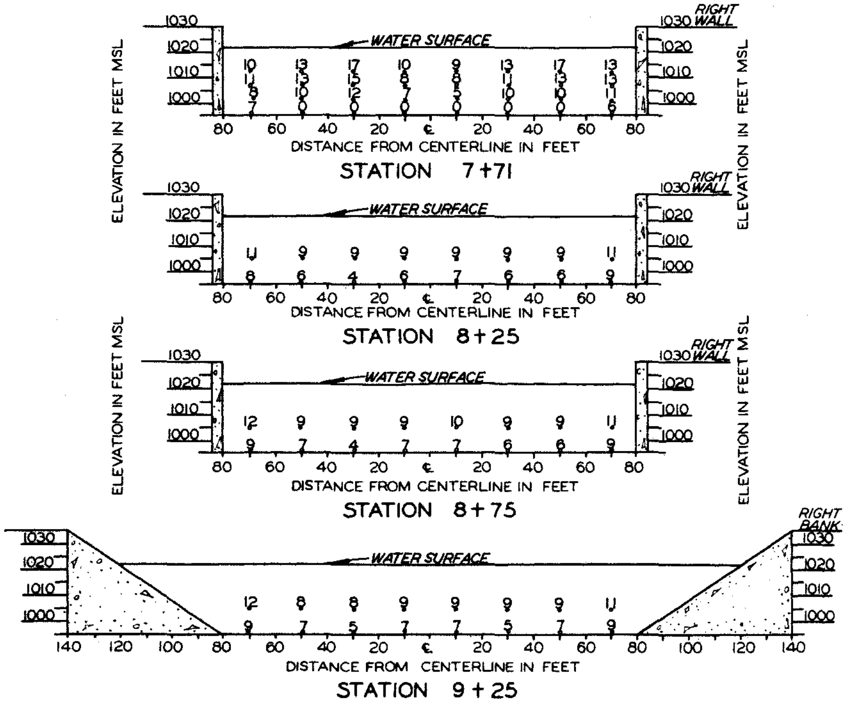
SCOUR AND WATER SURFACE PROFILES

NOTE: EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.
MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.
WATER SURFACE PROFILE OBTAINED WITH BED MOLDED IN CEMENT MORTAR.

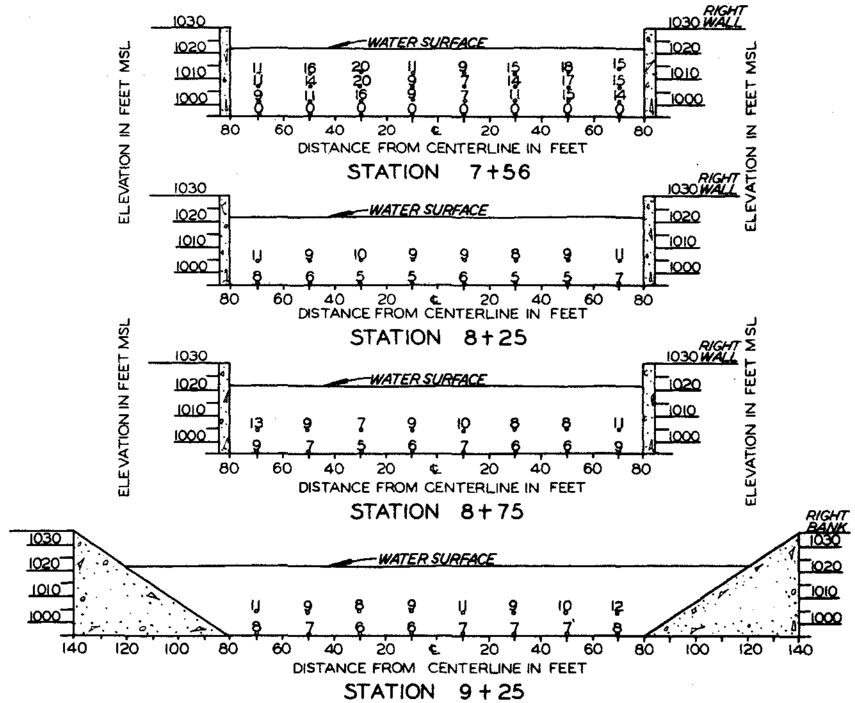
# SCOUR PATTERN

## DIVIDING WALL SHORTENED 50 FT
## STILLING BASIN FLOOR ELEVATION 977.0

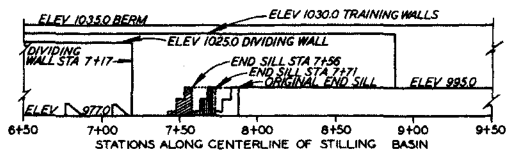
| | |
|---|---|
| END SILL AND EXIT CHANNEL ELEVATION | 995.0 |
| DISCHARGE RIGHT CONDUIT | 22,500 C F S |
| TAILWATER ELEVATION | 1017.0 |




STILLING BASIN LENGTH SHORTENED 15 FEET TO STATION 7+71




STILLING BASIN LENGTH SHORTENED 30 FEET TO STATION 7+56




CENTERLINE ELEVATION INDICATING STILLING BASIN LENGTHS

NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

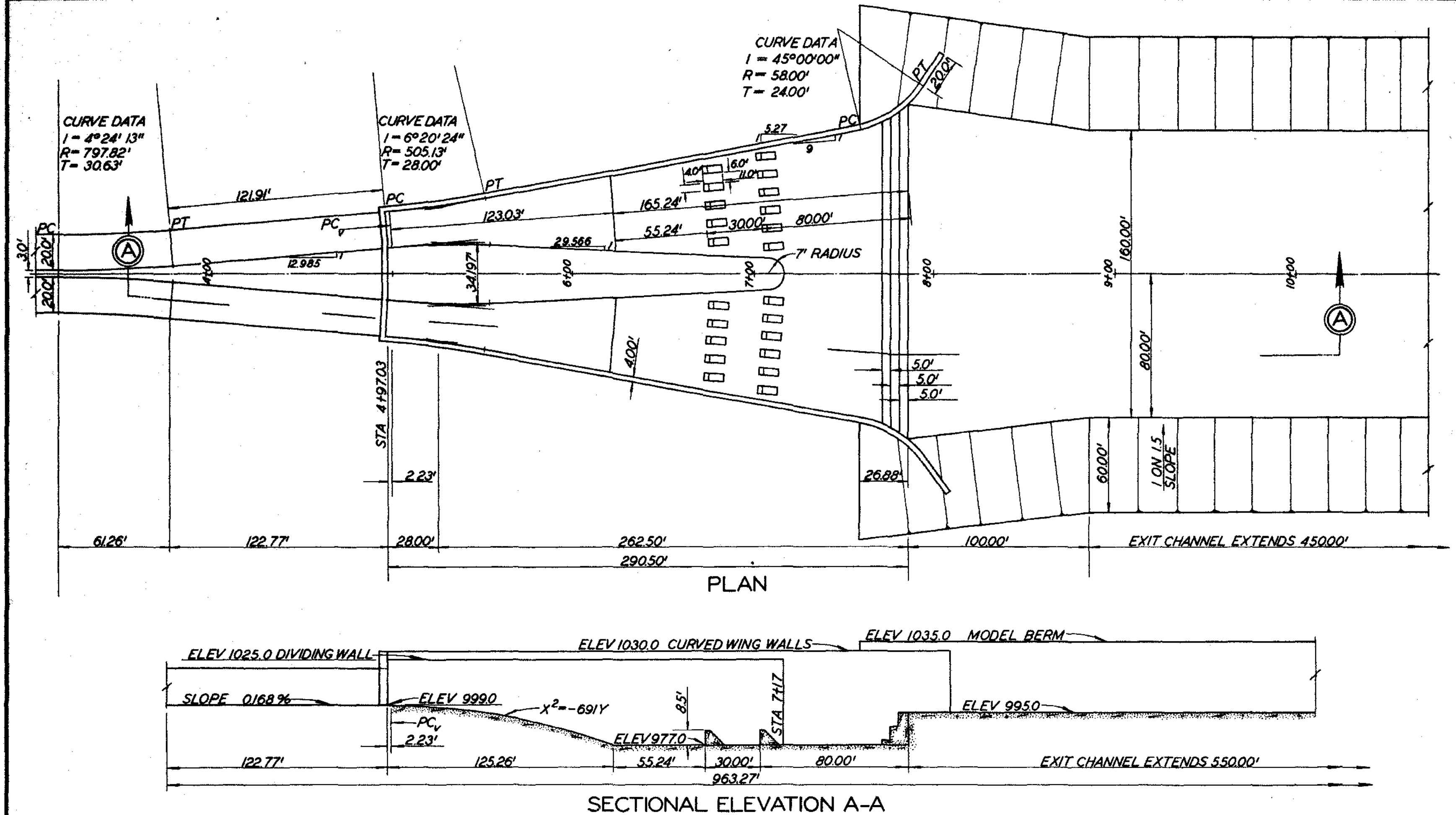
VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR.

# VELOCITY COMPARISON

## STILLING BASIN LENGTH SHORTENED 15 AND 30 FT

| | |
|---|---|
| DIVIDING WALL AT STATION | 7+17 |
| STILLING BASIN FLOOR AT ELEVATION | 977.0 |
| DISCHARGE | 45,000 |
| TAILWATER ELEVATION | 1022.2 |

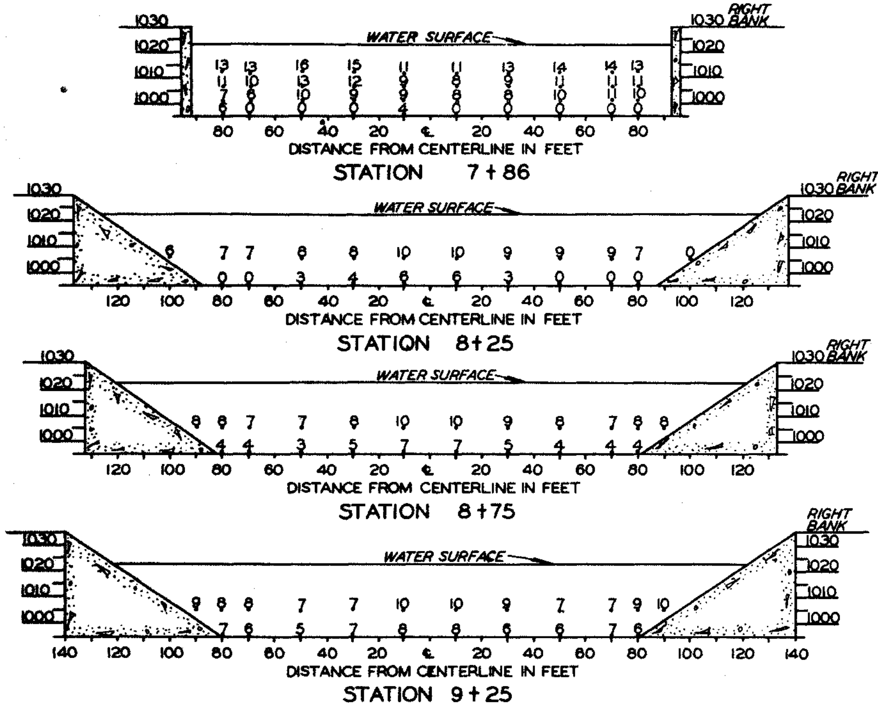



NOTE: ELEVATIONS ARE IN FEET MEAN SEA LEVEL.
ALL VALUES ARE IN PROTOTYPE UNITS.

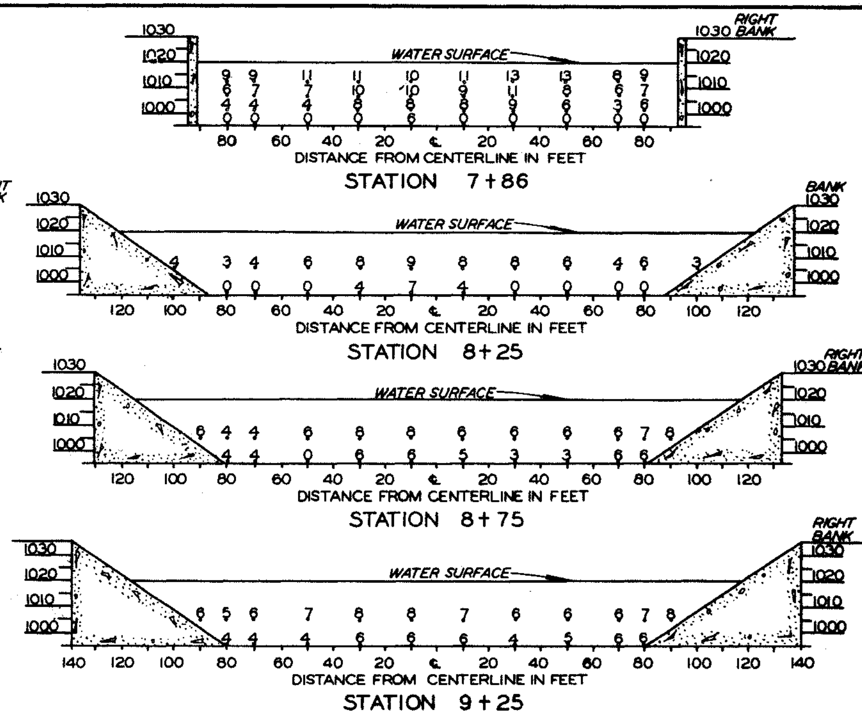
## STILLING BASIN DETAILS
### RECOMMENDED DESIGN

SCALE

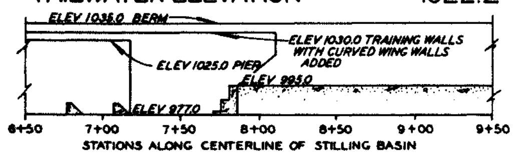
50 0 50 100 FT




DISCHARGE 45,000 CFS
TAILWATER ELEVATION 1022.2




DISCHARGE 35,000 CFS
TAILWATER ELEVATION 1020.2




RECOMMENDED STILLING BASIN AND EXIT CHANNEL

NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

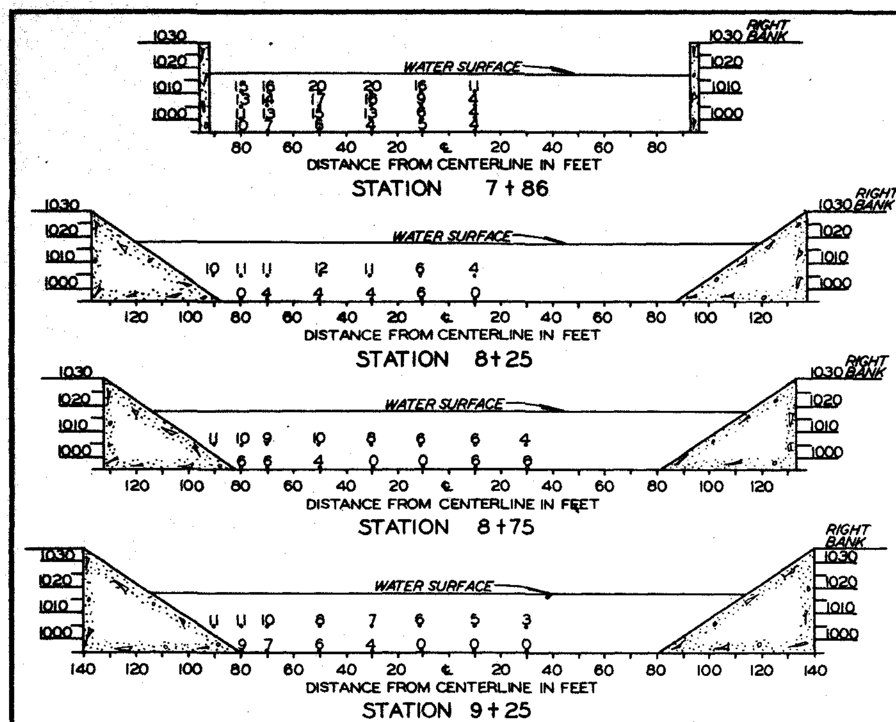
BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR.

ELEVATIONS ARE IN FEET MEAN SEA LEVEL.

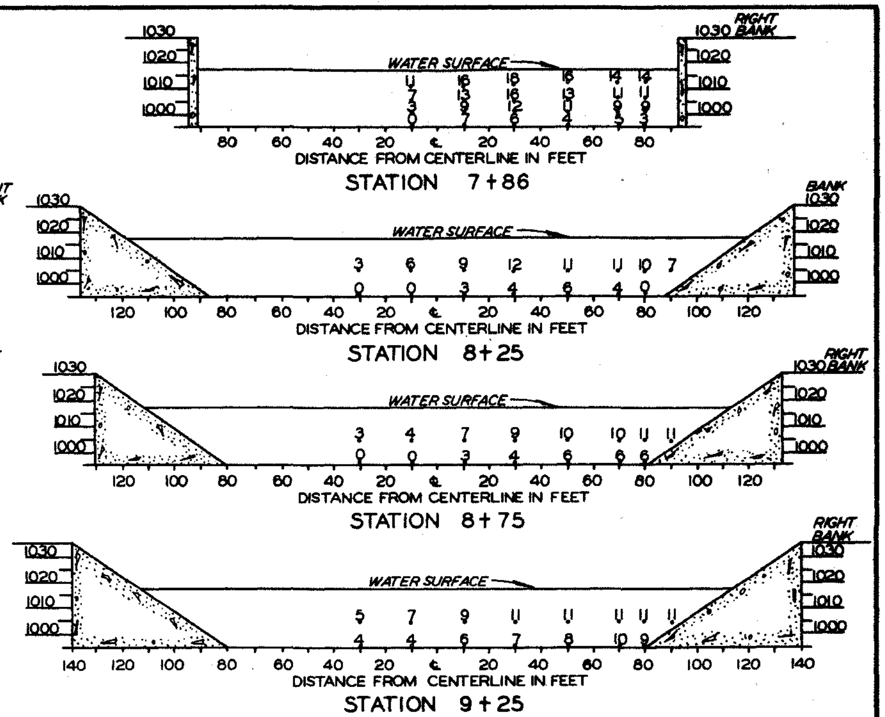
## VELOCITIES

RECOMMENDED DESIGN STILLING BASIN

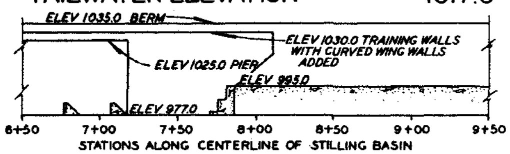
TWIN CONDUIT OPERATION




DISCHARGE LEFT CONDUIT 22,500 CFS
TAILWATER ELEVATION 1017.0




DISCHARGE RIGHT CONDUIT 22,500 CFS
TAILWATER ELEVATION 1017.0




RECOMMENDED STILLING BASIN AND EXIT CHANNEL

NOTE: VELOCITIES ARE RECORDED IN PROTOTYPE FEET PER SECOND.

VELOCITIES ARE IN A DOWNSTREAM DIRECTION EXCEPT WHEN PRECEDED BY A MINUS SIGN WHICH INDICATES UPSTREAM FLOW.

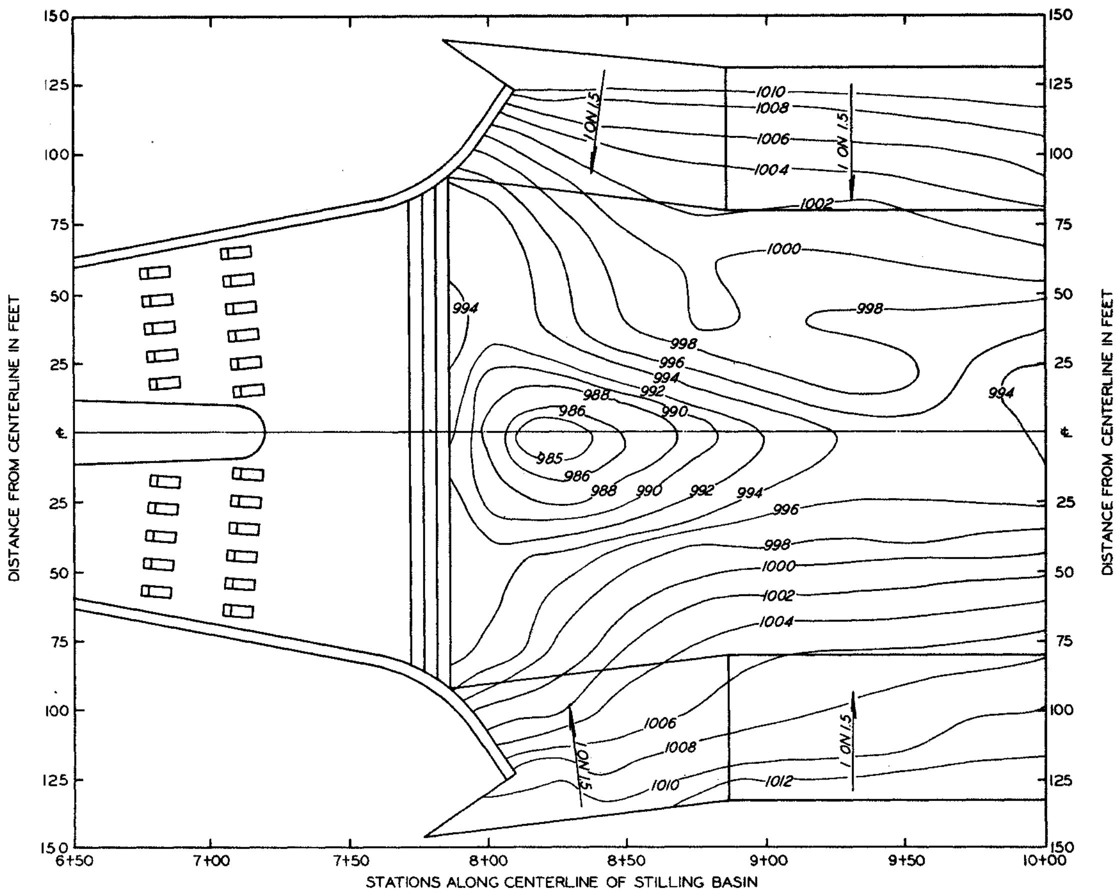
BED OF EXIT CHANNEL MOLDED IN CEMENT MORTAR.

ELEVATIONS ARE IN FEET MEAN SEA LEVEL.

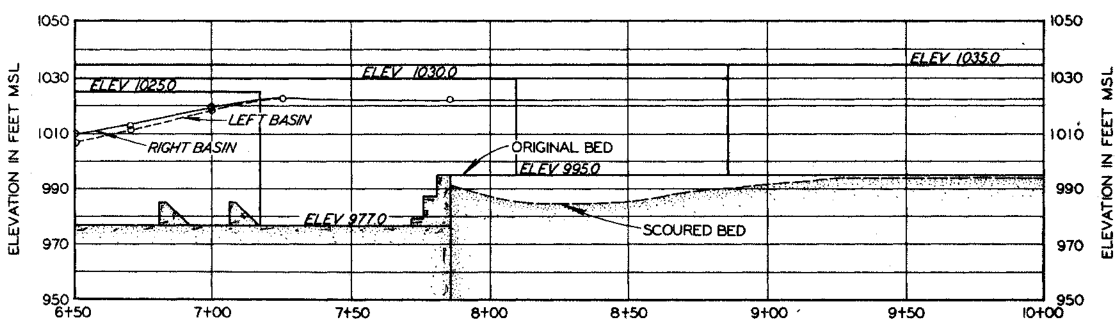
# VELOCITIES

RECOMMENDED DESIGN STILLING BASIN

SINGLE CONDUIT FLOW




SCOUR PATTERN



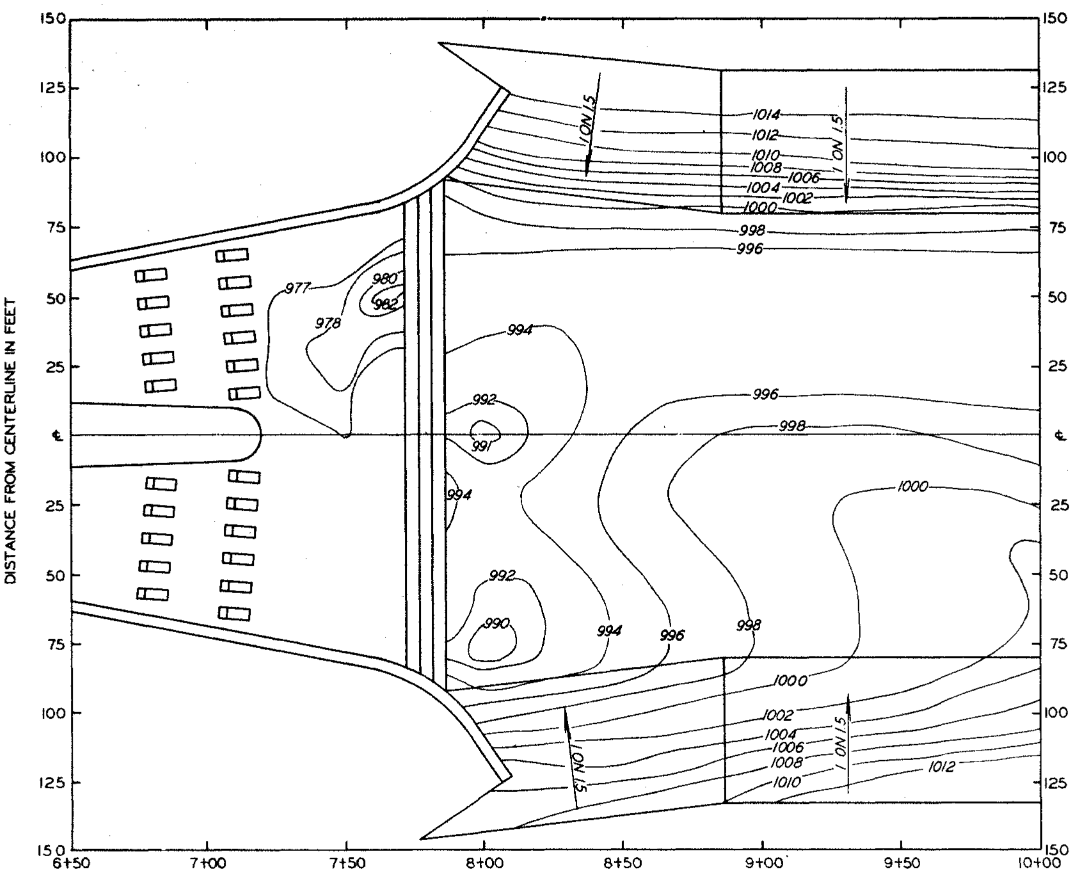

SCOUR AND WATER SURFACE PROFILES

NOTE: EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.
MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.
WATER SURFACE PROFILE OBTAINED WITH BED MOLDED IN CEMENT MORTAR.

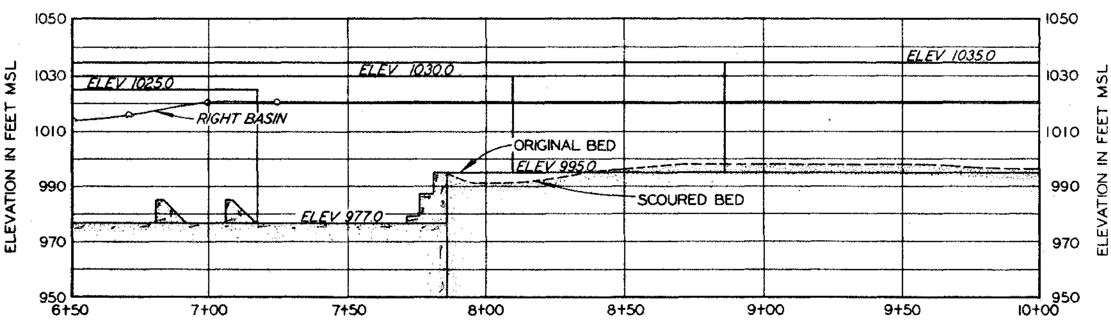
# SCOUR PATTERN

## RECOMMENDED DESIGN STILLING BASIN
## TWIN CONDUIT OPERATION

| | |
|---|---|
| DISCHARGE | 45,000 CFS |
| TAILWATER ELEVATION | 1022.2 |




SCOUR PATTERN




SCOUR AND WATER SURFACE PROFILES

NOTE: EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.
MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.
WATER SURFACE PROFILE OBTAINED WITH BED MOLDED IN CEMENT MORTAR.

## SCOUR PATTERN

### RECOMMENDED DESIGN STILLING BASIN RIGHT CONDUIT FLOW

DISCHARGE RIGHT CONDUIT 22,500 CFS
TAILWATER ELEVATION 1017.0